Program of Studies
for
Senior High School

BULLETIN 5b

Guide for Practical and Experimental Work

— IN —

PHYSICS 2
CHEMISTRY 2
BIOLOGY 2

Additional copies of this Bulletin may be had from the General Office of the Department of Education at 20 cents per copy.

EDMONTON, SEPTEMBER, 1949

FOREWORD

"Laboratory work" in any one of the senior science courses is NOT a course in itself, separate and distinct from a course in theory. It is not designed to produce research students, but rather to illuminate the facts and theory of the subject, and provide, along with other activities, some meaningful experience for the student that may facilitate his comprehension. There must be a close relationship between the teaching of theory in the classroom and the practical work in the laboratory. Failure to synchronize theory and practical work defeats the purpose of a course in science. Students who memorize the theory without having had the benefit of practical exercises cannot meet the requirements of any science course; but, on the other hand, there can be little justification for a procedure that permits the practical work to outrun the theory, or that concentrates the practical work in a few weeks at the end of the term.

The outlines for practical work in chemistry, physics and biology given in this bulletin are suggestive rather than prescriptive. More exercises may be required to meet the needs of a particular class; and other and better exercises may be devised by the teacher in consultation with his students. The suggested outlines will, however, save some of the teachers' and students' time.

This bulletin is to be used as a guide to practical and experimental work and not as a student workbook. That is, students should not write answers to questions, give observations or tabulate results in this book but should be required to make all notations in a suitable notebook.

It is recommended that, wherever possible, experiments be performed by groups of two and that each student be required to keep a record of the experiments carried out. Written reports on selected experiments should be done in an approved manner, using carefully-labelled diagrams, equations or statements of basic scientific principles when any or all of these will add to the quality of the report. These written reports should be kept in a separate notebook, looseleaf preferred.

THE SCIENCE LABORATORY

Some of the statements made in the introductory section of Bulletin 5a may be appropriately repeated here. It was mentioned, for example, that some schools do not have the use of a separate room for a science laboratory; hence all practical and experimental work has to be done in the regular classroom. In such cases, the comments made concerning the science room should be carefully noted.

Where a separate room for laboratory work is available, it is best that it be conveniently located in the school building, well lighted and ventilated, supplied with good apparatus, adequately furnished and given proper care.

ATTENTION TO ENGLISH

The suggestions found in Bulletin 5a under the heading, "The Importance and place of English in the Science Courses", are also appropriate for this bulletin. In the section referred to, it was stated that students of science should be able to participate successfully in certain science activities that are common in their school and everyday lives. The activities named are:

1. Reading,
2. Taking part in discussions,
3. Preparing and making reports,
4. Giving descriptions and explanations.

All these activities are present in a well-balanced science course. In laboratory work particular attention should be given to activities 3 and 4. In these activities several particular abilities will have to receive special attention, such as mastery of vocabulary, spelling, punctuation and effective expression. Where basic principles are involved, they should be stated accurately and, in written reports, placed in a prominent position. In all cases, the instructor is at liberty to devise methods of procedure for his students that will meet desired objectives and requirements of the respective courses.

PHYSICS 2

The experimental work in Physics 2 will consist partly of experiments demonstrated by the teacher and partly of experiments designed for individual work or for groups of two or three students working together.

The twenty experiments in this outline have been selected for individual work on the basis that each requires some quantitative observations and involves some definite calculations leading to a specific result. Completed experiments, with a reasonable degree of accuracy, should be expected of all students.

The experiments are in two groups, the first ten dealing with Mechanics and Heat, the second ten dealing with Magnetism and Electricity. A minimum of seven in each group should be done by each student.

Owing to the fact that much of the apparatus for these experiments is expensive, it is suggested that only one or two sets of apparatus for each experiment should be provided. This will make it necessary for groups to perform the experiments in rotation.

The list of apparatus provided below is based on the assumption that many of the experiments will be running concurrently where larger classes are involved; hence the necessity for several of such instruments as ammeters and voltmeters. An adequate supply of such equipment should be built up in each school over a period of years. This list does not include demonstration equipment. There is practically no limit to the amount of equipment a teacher will find useful in teaching this course. It can be added to indefinitely, but much of it may be improvised or constructed by students at home or in the school shop.

List of Apparatus for Physics 2

3 spring balances (250 gm.)
3 spring balances (2000 gm.)
*1 spring balance (15 kgm.)
*1 parallelogram of forces board
1 1″ perforated metal ball
3 large retort stands and clamps (iron)
1 wooden stand and clamp
1 board for friction experiments
1 set of kilogram weights on hook
1 set of gram weights on hook
1 wheel and axle
1 metre stick
1 inclined plane and car

3 insulated calorimeters
6 thermometers (centigrade)
2 thermometers (Fahrenheit)
3 physical balances
3 sets of metric weights
1 aluminum block for specific heat experiment
*1 Liebig's condenser
*1 distilling flask
*1 boiler for heat experiments
2 water traps
1 Regnault's dewpoint hygrometer
1 wet and dry bulb hygrometer
6 bar magnets (6″ long)
1 horseshoe magnet
1 box of fine iron filings
1 roll of blue print paper
1 grooved board for bar magnets
1 demonstration Voltaic cell
6 zinc elements for the above
4 copper elements for the above
2 carbon elements for the above
3 Daniell cells
3 dry cells
3 voltmeters (low range, D.C. graduated in tenths)
3 ammeters (low range, D.C. graduated in tenths)
*1 voltmeter (A.C. 0-150 volts)
*1 ammeter (A.C. 0-10 amps.)
1 resistance box (plug-in type)
1 resistance box (dial type)
1 set of assorted standard resistances
1 variable resistance (0-3 ohms)
1 storage battery (6 volts)
6 knife switches (s.p.s.t.)
1 Wheatstone bridge (slidewire type)
1 D'Arsonval type galvanometer
12 pietenpol connectors
6 test clips
1 mercury barometer
1 galvanoscope (multiple coil type)
6 small compass needles (enclosed)
1 demonstration compass needle (open)
*1 St. Louis type demonstration electric motor
*3 40-watt lamps (Mazda)
*1 25-watt lamp (Mazda)
*1 60-watt lamp (Mazda)
*1 100-watt lamp (Mazda)
*1 16-c.p. carbon lamp
*1 32-c.p. carbon lamp
1 set primary and secondary coils with core.

In addition to the above, assorted beakers, flasks, test tubes, measuring cylinders, glass tubing, rubber tubing, rubber corks, tripods, bunsen burners or spirit lamps, reagent bottles, battery jars, porous cups, wire gauze and other chemical equipment will be needed.

Special chemicals for these experiments include:

Sulphuric acid
Nitric acid
Hydrochloric acid
Mercury
Copper sulfate
Sodium dichromate
Ether
Ethyl alcohol (95%)
Methyl alcohol

*The apparatus marked with an asterisk is less essential or expensive equipment which is required for only one experiment and could be omitted.

EXPERIMENT 1

The Parallelogram of Forces

Object: To demonstrate the proposition known as the parallelogram of forces, and to calculate the equilibrant of two forces acting at any angle.

Reference: "Modern Physics," Sections 131-136. Study the definitions of "Resultant of two Forces acting at any angle," and "Equilibrant of two or more forces."

Apparatus: Three spring balances graduated in grams, a small iron ring (diameter 1"), string, drawing paper, thumb tacks, **either** three 3" nails **or** perforated board and pins as listed in science catalogues.

Procedure: If the prepared board is available, tie three lengths of string to the iron ring, place the three pins in holes at the extreme ends of the board and adjust the three spring balances on the board so that when the three strings are tied to their hooks and their rings are placed over the pins they will each register a tension at about the middle of their scales.

If the board is not available, use the three 3" nails driven firmly into an old table or bench so that they form a triangle with sides about three feet long. The spring balances are attached to these nails and to the iron ring by means of lengths of string, with the iron ring approximately in the centre of the triangle. Place a sheet of drawing paper under the strings with the iron ring in the centre and attach to the board or table by means of

tacks. Make sure that the balances are stretched with as little friction as possible against the board or pins. Using a set square, mark two points vertically below each string, one at each end, so that when these points are joined with straight lines they will exactly represent the direction of each string.

Now read each spring balance as accurately as possible and record its value in grams on the paper along the string attached to it. Remove the balances from the pins, join up the points on the paper so that they meet in a point.

Along two of the lines mark off lengths proportional to the readings of the spring balances. A suitable scale might be 1 cm. to represent 20 gm. Taking these two lengths as the two adjacent sides of a parallelogram, complete the parallelogram using a compass to mark off equal opposite sides.

Draw the diagonal of the parallelogram, measure its length in centimetres and express it as a force in grams on the same scale as you used for the sides of the parallelogram.

Results: Is the diagonal of your parallelogram in the same straight line as the line representing the pull of the third balance? If your work was done accurately and the balances registered correctly with the minimum of friction, this should be the case.

Does the length of the diagonal in centimeters represent the same value in grams as the third balance?

Letter your diagram ABCD etc., and state in the lower right-hand corner of the paper which lines represent which forces, which is the resultant force and which is the equilibrant. Write a statement in ink of the proposition which you have thus demonstrated.

EXPERIMENT 2

The Simple Pendulum

Object: To study the laws governing the oscillation of a pendulum and to find the value of g, the acceleration due to gravity.

Reference: "Modern Physics," Sections 162-166. Study the definitions of "single vibration," "complete vibration," "period," "amplitude of vibration."

Apparatus: About 4 feet of strong thread, one inch metal ball perforated through the centre, or other suitable pendulum bob, clamp, stop watch or metronome. An ordinary watch with a seconds hand may be used if a stop watch or metronome is not available.

Procedure: (a) Tie the thread to the metal ball and secure the other end by means of a clamp, adjusting the length of the pendulum so that it is exactly one meter from the point of suspension to the centre of the bob. Pull the bob to one side through a small arc, not more than three inches, and release it. When it is swinging uniformly, take the time in seconds for it to make 30

single vibrations. Two students working together can do this quite accurately with an ordinary watch if one watches the pendulum and gives the time for starting and stopping the count, whilst the other observes the seconds hand of the watch.

Repeat the experiment with the pendulum swinging over a larger arc, say, six inches, and again with an arc of about one foot. Keep a record of your results.

(b) Shorten the thread so that the effective length of the pendulum is 25 cm., and determine the average period of oscillation; i.e., the time for one **complete** vibration of the pendulum. Use a small arc and take the average time for twenty complete swings, using several tries. Record the results.

(c) Repeat the experiment using a pendulum with an effective length of 64 cm. Record the average value for the period of oscillation.

Results: Tabulate your results from experiment (a) thus:

Exp. No.	Amplitude (approx.)	No. of single vibrations	No. of secs.	Period for single vib.

What is the relation between the time of vibration and the amplitude? State the result as a law. (See Section 163 of textbook.)

Tabulate your results from experiments (b) and (c) thus:

Exp. No.	Length	$\sqrt{}$ Length	Period for complete vib.	Value of g.
a				
b				
c				

How is the time of vibration related to the length of the pendulum? State this as a law. (See Section 163 of textbook.)

Determine the value of "g" by using the formula,

$$T = 2\pi\sqrt{\frac{l}{g}}$$

EXPERIMENT 3

The Coefficient of Friction

Object: To determine the coefficient of sliding friction and to compare it with rolling friction.

Reference: "Modern Physics," Sections 183-190. Study Section 187 and the definition of "coefficient of friction."

Apparatus: A board 5 ft. long and 4 or 5 in. wide, preferably of fir or other hard wood, planed and smoothed with sandpaper, a small block of the same material about 3″ x 5″ x 1″, spring balance, kilogram weights, small experimental car, string.

Procedure: (a) Insert a small hook in the centre of one end of the wooden block, suspend it from the spring balance and record its weight in grams. Lay the long board flat on a bench and rub the small wooden block over it several times. Attach a string to the hook on the block and tie the other end to the balance as in Fig. 221 of the textbook. Pull gently on the balance and tap on the board so that the block just starts moving. Read the balance at this instant. Repeat several times and determine the average force of friction. Record all readings in tabular form.

Now place a kilogram weight on the wooden block and repeat the experiment, again recording the readings of the balance and determining the average force of friction.

(b) Place a stop against one end of the board and lay the wooden block on the board. Raise the other end of the board until the block begins to slide down the slope. Note the approximate angle of repose; i.e., the greatest angle at which the block remains in equilibrium on the inclined plane. Place a support under the board and adjust the slope of the plane so that when gently tapped the block will begin to slide down the slope. Measure the vertical height of the slope and the length of the base line along the table. For accurate measurement, the slope of the triangle must be produced and the exact point at which it meets the table marked. The dimensions of the right-angled triangle should be carefully recorded and the angle of the plane at the base determined with a protractor.

(c) Lay the board flat and place the trolley car on it. Gently raise the board at one end until the car begins to move evenly down the slope. Determine the height and base of the triangle so obtained as before.

Now lock the wheels of the car with a wedge and repeat the experiment determining the dimensions of the slope down which the car slides with locked wheels.

Results: Determine from the data of experiment (a) the coefficient of sliding friction as worked out in Section 187 of the textbook.

Is the value the same when the block carried the kilogram weight?

From the data of experiments (b) and (c) the coefficient of friction may be determined by the formula,

$$\text{C.F.} = \frac{\text{Vertical height}}{\text{Length of base}}$$

How do the results of experiment (a) and (b) compare? These two methods should give approximately the same results.

The coefficient of friction may also be obtained by determin-

ing the tangent of the angle of friction. That is, if the angle between the board and the table at the base is **i**, the coefficient of friction $=\tan i$. The results of this method should again check with those obtained above.

From the data of experiment (c) determine the coefficient of rolling friction and the coefficient of sliding friction. Which is the greater?

Tabulate the results of experiments (a), (b), and (c) in three separate tables, setting forth the weights used, the force of friction, the dimensions of the slopes and the calculated coefficients for each set of values.

EXPERIMENT 4

Part A—The Wheel and Axle

Object: To determine the mechanical advantage of the wheel and axle.

Reference: "Modern Physics," Section 214-215. Study the method of determining the mechanical advantage of the wheel and axle as given in Section 214.

Apparatus: An experimental wheel and axle may be obtained from scientific supply companies, or it may be simply constructed by obtaining two wooden spools or cylinders, one large and the other small, and gluing them together coaxially. Nails may be driven into the centre of each spool to form an axle which can rest in two short lengths of glass tubing for bearings. The wheel and axle should turn symmetrically on these bearings which may be lubricated with oil to reduce friction. A small hole bored diagonally through the rim of each cylinder will provide points of attachment for strings. A small tray to carry weights may be made from the lid of a round can with holes bored around its rim for the supporting wires or string.

Procedure: Set up the wheel and axle and see that it turns without wobbling and with as little friction at the bearings as possible. Tie a string to the small wheel or axle and pass it around the circumference twice. To the other end of the string tie a 500 gm. weight. Tie a string to the large wheel and pass it around its circumference in the reverse direction to the string around the axle. Attach the tray, previously weighed, to the other end of this string. Now place weights in the tray until the wheel and axle remains in equilibrium with both weights hanging freely. Record the weights used and measure the diameters of the wheel and axle using a pair of calipers or dividers. Record the diameters in centimetres correct to the second decimal place.

Repeat the experiment using a 200 gm. weight and again with a 1000 gm. weight. Record the weights needed to balance these in each case.

Results: Determine the theoretical Mechanical Advantage of this system from the dimensions of wheel and axle as explained in Section 214 of the textbook. Determine the actual mechanical advantage by dividing the weight by the effort for each experi-

ment. Compare the theoretical mechanical advantage with the true mechanical advantage.

Tabulate results as follows:

Diam of Wheel (cm.)	Diam. of Axle (cm.)	Theor. M.A.	Weight Raised	Effort W+w	Actual M.A.

Note: In above table W is the weight placed in the tray, w is the weight of the tray.

Part B (optional).

Reference: "Modern Physics," Section 223.

Apparatus: Bicycle, kilogram weight, 15 kgm. spring balance, 2" tape, metre stick.

Procedure: Support the bicycle so that the back wheel will turn freely. Measure the diameter of the rear wheel in centimetres and determine its circumference.

Count the number of teeth in the two sprocket wheels and determine how many revolutions the rear wheel makes for one complete turn of the pedals. Check this experimentally. Measure the length of the pedal arm from centre to centre of the supporting axle. Determine the circumference of the circle traced out by a pedal in one revolution. This will give the distance the effort moves for one turn of the pedals. Determine the mechanical advantage of speed by dividing the distance of the resistance (circumference of rear wheel multiplied by the gear ratio) by the distance of the effort. The Mechanical Advantage of Force is the inverse of this. Why?

Now attach a one-kilogram weight to the tire of the rear wheel so that it hangs down vertically below the outer circumference of the wheel. A piece of 2" tape placed over the outer circumference of the tire and supporting the weight is a good method of doing this.

Hook the 15 kgm. spring balance to the centre of the pedal and pull upward, taking the reading of the balance when the pedal is in a horizontal position. Divide the resistance (1000 gm.) by the effort. This gives the actual Mechanical Advantage of Force.

Results: Tabulate all measurements and work out the actual and theoretical values for the Mechanical Advantage.

Is there a big difference as between the theoretical and actual values? Is the bicycle an efficient machine?

Note: If a 15 kgm. spring balance is not available the procedure may be reversed by tieing a large weight, say 10 kgm. or 10 lb., to the pedal and attaching a small spring balance to the

tire and pulling downwards to support the weight on the pedal. In this case, however, the weight of the spring balance must be added to its reading to determine the true value of the resistance.

EXPERIMENT 5

The Inclined Plane

Object: To determine the Mechanical Advantage of the Inclined Plane and to calculate the efficiency of this machine.

Reference: "Modern Physics," Sections 216 and 217. Also review Sections 203 and 204.

Apparatus: The Inclined Plane apparatus and car, weights, spring balance, metre stick, string. If the regular inclined plane apparatus as supplied by scientific manufacturing companies is not available, a smooth board 6 in. wide and five feet long and a model car made from a Meccano set with its bearings well lubricated may be used.

Procedure: Set up the inclined plane at an angle of about 30°. Weigh the car on the spring balance and attach a long string to the hook. Place it on the plane with a 500 gm. weight in it. Attach the string to the balance, pass the string over the pulley at the top of the plane and, applying a horizontal pull, determine the force required to pull the car up the slope. This force represents the effort required to overcome the pull of gravity and the friction.

Take a second reading as the car runs slowly down the plane. This represents the effort less the amount due to friction. The average of these two values gives the true force needed to overcome the pull of gravity down the plane.

Measure a distance of 100 cm. along the lower edge of the inclined plane from the point where it contacts the table, and mark the distance on the edge of the plane. Measure the vertical height of the plane at this point from the table. (If the plane is less than 100 cm. long, any other convenient distance may be measured.)

Results: Repeat the experiment twice changing the angle of the plane for each trial.

Tabulate all data as follows:

Exp. No.	Effort + Friction	Effort — Friction	Average Force	Resistance; i.e., Weight	$\frac{\text{Resistance}}{\text{Effort}}$
1.					
2.					
3.					

Exp. No.	Length	Height	L/H	Efficiency $= \frac{RxH}{ExL} \times 100$
1.				
2.				
3.				

Note: In the formula for efficiency given above E is the effort required to pull the car up the slope; i.e., Effort+Friction since, in this machine, useful work is only done when the weight is moved up the slope.

What is the theoretical Mechanical Advantage of the Inclined Plane? What is the actual M.A.? What is the relation between the Mechanical Advantage and the angle of the slope?

EXPERIMENT 6

Determination of Specific Heat

Object: To determine the specific heat of aluminum or other suitable metal by the method of mixtures.

Reference: "Modern Physics," Sections 269-272, with particular reference to Section 271.

Apparatus: Insulated calorimeter, thermometer, boiler **or** florence flask, burner, balance, set of weights, length of string, metal block **or** shot.

Note: In this experiment the best results are obtained using a block of aluminum, since aluminum has a high specific heat. The usual method of heating some lead shot in a test tube supported in the neck of a florence flask containing boiling water may, however, be used. Care must be taken in this case to see that the lead shot is uniformly heated and that the thermometer inserted in the shot measures the average temperature of the shot. In reading the thermometer always estimate fractions of a degree to the nearest tenth. A small error in the thermometer reading can result in a large error in the specific heat.

Method: Tie a piece of string to the metal block and weigh it. Or, if lead shot is to be used weigh out about 200 gm. of shot and transfer to a test tube. (A piece of heavy insulated wire twisted around the test tube serves both as a handle and as a means of supporting the test tube in the neck of the florence flask for heating.)

Put the aluminum in a boiler half full of water with the string hanging outside. Heat the boiler with a bunsen or other burner. Weigh the calorimeter (the inside vessel only, if it is a double insulated calorimeter). Fill the calorimeter 2/3 full of water and weigh it again. The water used should be several degrees below room temperature. Take the temperature of the steam in the boiler. Stir the water in the calorimeter gently with the thermometer and record its temperature.

Now raise the aluminum block so that it hangs only in the steam of the boiling water for a minute or so. Record the temperature of the metal as that of the steam in which it is suspended. Place the calorimeter in an insulating vessel supporting it in a fibre ring or cotton wool packing. Quickly transfer the aluminum block which should be quite dry to the calorimeter and take the resulting temperature, moving the block up and down to ensure thorough mixing of the water. If lead shot is used it may be quickly dumped into the water and stirred with the thermometer.

Results: Tabulate all readings and weights and calculate the specific heat of the metal in the manner illustrated in Section 271 of the textbook.

Compare your result for the specific heat of the metal with the value given in Table 6, Appendix B, "Modern Physics."

Calculate the percentage error thus: $\frac{\text{Actual error}}{\text{Correct value}} \times 100.$

In your conclusion to the experiment indicate the most probable sources of error.

EXPERIMENT 7

Heat of Fusion of Ice

Object: To determine how many calories of heat are required to melt one gram of ice at its melting point.

Reference: "Modern Physics," Sections 277-279. Study the method of solving the problem on heat of fusion in Section 278.

Apparatus: Insulated calorimeter, balance, weights, thermometer, ice, towel. The thermometer should be graduated in Centigrade degrees and should be read carefully to the nearest tenth of a degree.

Procedure: Weigh the calorimeter—inside vessel only; fill it about 2/3 full of water at 40°C; weigh again. The difference in the two weighings will give the weight of water taken. Break up the ice into pieces about one inch across. Take the temperature of the water in the calorimeter as accurately as possible having first placed the calorimeter in the insulating vessel. Remove excess moisture from the ice by wiping it with a cloth and introduce it into the calorimeter taking care not to lose any of the water by splashing. Stir the water constantly and take the temperature, adding more ice from time to time until the temperature is around 5°C. Stir until the ice is all melted and take the final temperature accurately.

Now weigh the calorimeter to determine the weight of ice which has been added.

Results: Following the method illustrated in Section 278 of the textbook, calculate the heat of fusion of ice in calories per gram. Tabulate all weights and temperatures neatly and show all calculations. Determine the percentage error in your result. Indicate the chief sources of error which you think may have arisen in your experiment. If these include errors of manipulation, repeat the experiment and try to get a more accurate result.

EXPERIMENT 8

Boiling Point

Object: To determine the boiling point of certain liquids and to illustrate the process of fractional distillation.

Reference: "Modern Physics," Sections 288-290. Study carefully the correct method of setting up a condenser as illustrated in Fig. 334, page 242 of the textbook.

Apparatus: A Liebig's condenser, distilling flask, 25 cc. graduate, thermometer, receiving flask, alcohol, 10% solution of salt water.

Note: Wood alcohol, used for spirit lamps, is methyl alcohol, B.P. 66°C. Commercial grain alcohol is 95% ethyl alcohol, B.P. 78°C. Rubbing alcohol is chiefly ethyl with an admixture of methyl and other ingredients to "denature" it.

Procedure: Set up the apparatus as shown in Fig. 334, p. 242 of the textbook.

(a) Pour 100 cc. of tap water into the distilling flask and heat it to boiling. Have the bulb of the thermometer one inch from the surface of the water. When the thermometer remains steady take the temperature. If a mercury barometer is available take the atmospheric pressure in millimetres of mercury. Record these readings. Boil the water for two or three minutes and again record the boiling temperature.

(b) Replace the water in the distilling flask by 100 cc. of alcohol and determine its boiling point. Use a clean receiver for each distillation.

Pour the alcohol that has distilled over back into the flask and add 100 cc. of water. Determine the boiling point of the mixture. Continue to boil the mixture until 25 cc. has distilled over. Again record the boiling temperature.

Repeat with each of three more portions of 25 cc. of distillate, taking the temperature after each. Save the alcohol for future use.

(c) Throw away the liquid left in the distilling flask, wash out flask and pour in 100 cc. of 10% salt solution. Determine the boiling point at intervals of three minutes as long as time permits.

Results: (a) What is the boiling point of water? Does the B.P. rise with continued boiling? Refer to Table 9, Appendix B of the textbook. At what temperature should water boil at the recorded atmospheric pressure? How does this check with your recorded B.P.?

(b) What is the boiling point of pure alcohol? Is it ethyl or methyl alcohol? What is the boiling point of a mixture of alcohol and water? How does the boiling point change for the successive distillate fractions? How may this be explained?

(c) Tabulate the data from experiment (c). Account for any change in the boiling point of the salt solution.

EXPERIMENT 9

Heat of Vaporization of Water

Object: To determine the number of heat units required to change one gram of water into steam at its boiling point.

Reference: "Modern Physics," Sections 291-293. Study the method of determining the heat of vaporization of water as worked out in Section 292.

Apparatus: Steam boiler, water trap, rubber tubing, glass tube, balance, weights, insulated calorimeter, Centrigrade thermometer.

Note: If a copper boiler is not available, fit up a florence flask half full of water, having a bent delivery tube passing through a one-holed rubber stopper. Heat it over wire gauze on a tripod.

Procedure: Attach the water trap to the outlet pipe of the boiler or florence flask by means of rubber tubing. While the water is heating weigh the inside calorimeter vessel; fill it two-thirds full of water at about 5°C. (Snow or ice may be added to reduce the temperature of the tap water if necessary.) Weigh again to determine the weight of cold water in the calorimeter.

Attach the glass tube to the lower end of the water trap by means of rubber tubing. Take the temperature of the water in the calorimeter reading accurately to tenths of a degree. Place the glass tube below the surface of water in the insulated calorimeter (Fig. 337, textbook), and pass a steady stream of steam into the calorimeter until the temperature has risen to about 40°C. Remove the delivery tube, stir the water in the calorimeter and determine its temperature. Now weigh the calorimeter to determine what weight of steam has condensed in the water.

Take the temperature of the steam while the water is still boiling in the boiler.

Results: Following the procedure illustrated in the textbook (Section 292), tabulate all data and calculate the heat of vaporization of water.

Compare your result with that given in table 6, Appendix B, of the textbook, and estimate the percentage error. Indicate the most probable sources of error in this method.

EXPERIMENT 10

Dew Point and Relative Humidity

Object: To determine the dew point and the relative humidity of the air in the room.

Reference: "Modern Physics," Sections 300-306. See also "Elements of Physics," by Merchant and Chant, Sections 242-248, for a description of Regnault's dew-point hygrometer and the method of determining the relative humidity from the dew point.

Apparatus: Either a Regnault's polished cup hygrometer **or** a highly polished metal cup, ether, ice, thermometer (Fahrenheit); either a hygrodeik or a wet-bulb thermometer prepared by tieing a fresh spirit lamp wick around the bulb of a Fahrenheit thermometer, the lower end of the wick dipping into distilled water.

Note: If only Centigrade thermometers are available, refer to the table on p. 258, "Elements of Physics," by Merchant and Chant, for working out the relative humidity from the dew point.

Procedure: (a) Using Regnault's hygrometer. Pour into the polished cup about 5 cc. of ether. Adjust the thermometer, bent delivery tube and straight exit tube in the cork so that the bent delivery tube is below the surface of the ether but the outlet tube and thermometer bulb is above the ether. Attach an atomizer bulb to the bent delivery tube and gently force air through the ether so as to cause it to evaporate rapidly. Observe the drop in the thermometer and without breathing on the polished cup note the moment that a faint film of moisture appears on its surface. Immediately read the thermometer and record reading. Stop blowing air through the ether and watch the film of moisture on the polished cup. Record the temperature at which the film disappears. The average of these is the dew point. Repeat the experiment twice more and take the average value of the dew point.

(b) A polished cup or tin can may be used as follows: Fill the cup one-third full of water at room temperature. Add ice and stir with a thermometer until a film of moisture appears on the metal cup. Record the temperature at which the film appears and when it disappears. The average is the dew point. Repeat the experiment twice, using a fresh supply of water and ice.

Note: It may be necessary to add warm water to make the film disappear from the metal surface.

In either method (a) or (b) record the room temperature. Using a hygrodeik or wet-and-dry bulb hygrometer, determine the relative humidity by reading the two thermometers. The wet bulb should be gently fanned with a piece of stiff paper to obtain an accurate reading. Record the two readings.

Results: (a) Having determined the dew point in Fahrenheit degrees, refer to Table 5, Appendix B, "Modern Physics," and determine the moisture capacity in grains per cubic foot at the dew point and also at the temperature of the room. The relative humidity may then be determined by the following formula:

$$\text{Relative Humidity} = \frac{\text{Water Vapour capacity at dew point}}{\text{Water Vapour capacity at room temp.}} \times 100.$$

If a Centigrade thermometer has been used, the temperature may be converted into Fahrenheit readings, **or** the table referred to above in "Elements of Physics," by Merchant and Chant, may be used.

From the wet-and-dry bulb thermometer readings determine the relative humidity by reference to Table 16, Appendix B, of "Modern Physics."

Compare your results for the relative humidity of the room by the two methods. If there is not a fairly close agreement (within 5%) by the two methods, indicate in your conclusion which method you consider to be the most accurate.

EXPERIMENT 11

Lines of Magnetic Force

Object: To map the lines of force about magnets.

Reference: "Modern Physics," Sections 510-513. Look up,

in an encyclopedia or chemistry textbook, the method of preparing blue print paper. This makes a good chemistry project. The paper may be bought at little expense from a supply house.

Apparatus: Two bar magnets, horseshoe magnet with armature, iron filings, sieve or perforated metal box, pan, pins, blue print paper, board 1 ft. square with grooves cut parallel to hold bar magnets and of the same depth as the thickness of the magnets.

Procedure: Place a bar magnet in the grooved board in a part of the room where the light is subdued. Pin a sheet of blue print paper (9 x 11 in.) with the sensitive side up on the board so that the bar magnet is below the centre of the paper. Sprinkle iron filings in a thin layer evenly over the surface of the paper. Tap gently with the fingers until the filings arrange themselves in the direction of the lines of force. Without disturbing the arrangement of the iron filings, hold the board so that the paper is exposed to direct sunlight for about five minutes. At the end of this time the paper should have acquired a brownish colour. Remove the pins, shake off the filings into a pan, and develop the print by washing it in water until all the yellow colour has disappeared.

Spread the blue print on a pane of glass to dry, face down.

Repeat the experiment with two bar magnets placed with like poles adjacent, with unlike poles adjacent, and with a horseshoe magnet.

Results: When the blue prints are dry, label each, trim them to a suitable size and preserve them in your notebook. Compare the results with the diagrams shown in your textbook. Are there any irregularities in the lines of force shown on your blue prints? Comment on the possible cause of these.

Note: If time does not permit each group to do all of these, they may be divided up among the groups and the results put on display for the whole class to study. Other arrangements, such as two magnets placed at right angles in the form of a cross, or three bar magnets forming a triangle, or a magnet with a soft iron ring to illustrate shielding may be tried.

EXPERIMENT 12

The Voltaic Cell

Object: To set up a simple voltaic cell and to study its action.

Reference: "Modern Physics," Sections 545-550.

Apparatus: A simple demonstration cell, consisting of a glass jar with removable clamps to support the elements, two zinc strips, copper strip, carbon rod, D.C. voltmeter (1-15 volts or lower) Daniell cell, amalgamating fluid, No. 18 insulated copper wire.

Note: The amalgamating fluid may be prepared in the chemistry lab. by dissolving 5 cc. of mercury in aqua regia (60 cc. of nitric acid mixed with 200 cc. of hydrochloric acid).

Procedure: Prepare some diluted sulphuric acid, 1 part acid to 20 parts water; fill the glass jar one-third full with the acid and place a strip of zinc in it. What gas is given off? Complete the equation: $Zn+H_2SO_4$——

Note the colour of the zinc after a minute or two. What impurity in the zinc causes this appearance? (See Section 549, textbook.) What is meant by local action and how is it related to this impurity?

Dip one end of the zinc strip (2 or 3 in. of it) in the amalgamating fluid. Leave it for one minute, then remove, rinse and wipe dry. Describe its appearance.

Now put the amalgamated zinc strip in the sulfuric acid. How does its behavior compare with the previous action of the zinc strip? Explain the advantage of coating the zinc with mercury.

Remove the zinc strip from the acid, wash it and place it in a beaker or in the sink. Avoid spilling or splashing the acid; it is very corrosive.

Place a copper strip in the acid. Is there any action? Repeat using a carbon strip. Any action?

While the carbon is still in the acid, place the amalgamated zinc strip also in the acid but not touching the carbon. Is there any action visible when the cell is on open circuit? Attach the carbon and zinc strips to the terminals of the demonstration cell and attach the terminals to the voltmeter using the copper wire. Observe the action of the cell and note the strip from which hydrogen gas rises. Record this. Record also the reading of the voltmeter. This is the E.M.F. of the cell.

Short-circuit the cell by joining the two terminals by a short length of heavy copper wire. Leave it for a few minutes, then remove the shunt wire and again read the voltmeter. Record this. What is the appearance of the carbon strip now? What is the name for this effect?

Now lift the strips from the solution, wipe off the bubbles of gas and replace in the solution. Read the voltmeter and record. Does the voltage return to its original value? Again short-circuit the cell with the shunt wire until it is polarized. Add a few crystals of sodium or potassium dichromate to the sulfuric acid and stir. What is the effect of the dichromate crystals on the reading of the voltmeter? What kind of an agent is potassium or sodium dichromate? What is the effect on hydrogen? What is the essential property of a good depolarizer?

If time permits, set up the Daniell cell as follows: In the porous jar pour dilute sulfuric acid (1 of acid to 20 of water). Place an amalgamated zinc strip in the acid. Place the porous jar in the glass battery jar and fill the latter with a saturated solution of copper sulfate to the same depth as the acid in the porous jar. Insert the copper plate in the solution of copper sulfate. Allow time for the liquid to soak through the porous vessel and determine the E.M.F. of the cell with a voltmeter. Record the reading. Short-circuit the cell with the copper wire as before for two minutes and again record the voltage. Does this cell polarize?

Remove the copper plate and examine it. Is there a deposit on its surface? What is it? The action at the positive plate is represented by this equation:

$$H_2+CuSO_4=H_2SO_4+Cu.$$

If the Daniell cell is to be left standing for future use connect it in series with a 40 ohm resistance.

Results: Tabulate all observations and readings and summarize your conclusions as to the cause and remedy for (a) Local action, (b) Polarization in the voltaic cell.

Draw a diagram of the Daniell cell and explain its operation.

EXPERIMENT 13

Grouping of Cells

Object: To study the different ways in which cells may be grouped and to determine the advantage of one method over another.

Reference: "Modern Physics," Sections 555-559. Study the rules which apply to (a) cells in series, and (b) cells in parallel as listed in Section 558.

Apparatus: Three Daniell cells, voltmeter, ammeter, resistance coils, No. 18 insulated copper wire.

Note: A gravity cell is a form of Daniell cell that may be used for this experiment. The simple voltaic cell is not suitable owing to polarization. Three dry cells may be used but since their internal resistance is very low, it may not be easy to show the advantage of parallel connections for certain resistances with them.

Procedure: Connect a Daniell cell to the voltmeter by means of No. 18 copper wire and determine the E.M.F. Disconnect the voltmeter and connect in an ammeter and determine the amperage without other external resistance. Record the voltage and amperage. Connect the cell to a resistance of about 5-30 ohms and determine the amperage.

Connect three Daniell cells in series (Fig. 607, textbook) and test the combined E.M.F. with a voltmeter connected across the outside terminals of the series group. Record the voltage.

Now connect the three cells in series with the ammeter and a 40 ohms resistance. Record the amperage. Note that the external resistance of 40 ohms is large compared with the combined internal resistance of the cells.

Now connect the three cells in series directly to the ammeter. Record the amperage. In this case the external resistance, that of the ammeter and connecting wires, is quite low, less than the internal resistance of the cells.

Repeat the procedure using the three cells in parallel (Fig. 609, textbook). Record the voltage and amperage alone, and when the parallel group of cells is connected with the 40 ohm resistance in series with the ammeter.

Results: Tabulate the data as follows:

Grouping	Voltage	Maximum current	Current with 40 ohms R.
Single cell			
Three cells in series			
Three cells in parallel			

From the tabulated results indicate which method of grouping gives the maximum current: (a) when the external resistance is large compared to the internal resistance, (b) when the external resistance is smaller than the internal resistance.

EXPERIMENT 14

Ohm's Law

Object: To determine the resistance of an unknown resistor by the application of Ohm's law.

Reference: "Modern Physics," Section 553 and the first part of Section 619. For a more detailed explanation of Ohm's law as used for the determination of the resistance of a conductor, read "Elements of Physics," Sections 535-536. Note Fig. 610 in "Elements of Physics" for the method of connecting the apparatus for this experiment.

Apparatus: Ammeter, voltmeter (these should be graduated in tenths), rheostat or resistance box, battery of 5 or 6 volts, No. 18 wire for connections, **or** Pietenpol connectors, a length of resistance wire of unknown resistance as supplied by your teacher. This may be of any value between one ohm and 30 ohms.

Procedure: Connect in series the following: Battery, knife switch, rheostat or variable resistance box, unknown resistor, ammeter. Across the ends of the unknown resistor connect in parallel the voltmeter. Set the rheostat so as to include only a few turns of wire, or, if a resistance box is used, set it at one ohm.

Close the knife switch and immediately take the readings of both voltmeter and ammeter, reading to the nearest hundredth of an ampere or volt. **Note:** If the instruments are graduated in tenths, this will involve estimating the fractions of a division by judging with the eye the approximate fraction and expressing it as tenths. This will give the second decimal point in your reading. The knife switch should not be left closed for more than a half minute at a time, as the resistors will heat up and the resistance change while you are reading the instruments. Record the readings in a table as shown below. With the knife switch open, change the position of the rheostat or set the variable resistance

at 2 ohms and, closing the switch, again take readings of the ammeter and voltmeter. Repeat the experiment with a gradual increase in the resistance of the variable resistance taking readings of the ammeter and voltmeter each time. Obtain five sets of readings.

Results: Tabulate all data as follows:

Exp. No.	Voltmeter Reading	Ammeter Reading	Resistance in ohms $R=\frac{E}{I}$

Is the value for R, i.e., the unknown resistance, constant?

Take the average value of the five trials. If the material of the unknown resistance wire is known, measure its length and diameter (micrometer screw gauge) expressed in feet and mils and, applying the formula on p. 442 of "Modern Physics," calculate the resistance in ohms. Compare this value with the method of your experiment. Which do you consider the more accurate?

EXPERIMENT 15

The Wheatstone Bridge

Object: To determine the resistance of a conductor by the method of Wheatstone's Bridge.

Reference: "Modern Physics," Section 619. Study Fig. 683, p. 492, for the method of connecting the apparatus.

Apparatus: A slide-wire Wheatstone bridge, dry cell, D'Arsonval type of galvanometer, resistance box, an s.p.s.t. knife switch, connectors and an unknown resistance to be determined.

Procedure: Connect up the apparatus in the manner illustrated in Fig. 683 of the textbook. Use short lengths of No. 18 wire for the connectors. Place the resistor to be determined at X; connect in the adjustable resistance box at R. Connect the galvanometer across the points DK, using a short wire at D but a piece about 50 cm. long from the galvanometer to K. Connect the dry cell across the ends of the German silver wire AC, inserting a single-pole-single-throw switch between the battery and the wire.

Note: This is not shown in Fig. 683, but it is advisable so that the battery circuit can be opened when readings are not being taken, thus avoiding wastage and overheating of the resistance wires.

Slide the contact key to the 50 cm. mark and remove the 100-ohm plug from the resistance box. This introduces a resistance of 100 ohms at R. Now press down the key K and observe the needle of the galvanometer. **Note:** Make sure the galvanometer needle is able to turn freely and that the coil to which it is attached does not touch at any point as it swings. The reading should be zero when no current is passing through the galvanometer. The needle will probably jump violently when the key K is depressed. Adjust the resistances in the box R, either more or less until the motion of the needle is no longer violent and it moves over a few degrees of the scale.

Note: The plugs in the resistance box should be pressed in firmly to make good contact each time they are replaced.

To make the final adjustment so that the bridge is "balanced" and the galvanometer registers zero deflection, move the sliding key K to right or left as may be required until, on depressing the key, the galvanometer registers zero.

Read the value of the resistances in the resistance box and the exact position of the key K to the nearest millimetre at the point where it touches the wire. Record these.

Results: Tabulate the data and, using the method explained on p. 492 of the textbook, work out the value of the unknown resistor X in ohms.

Knowing the dimensions of the resistor, i.e., its length in feet and its diameter in mils, determine the value of K in the formula for resistance.

$$R=\frac{Kl.}{d^2}$$

Compare this value with the accepted value for the material of the resistor as given in Table 15, Appendix B, of the textbook.

EXPERIMENT 16

Internal Resistance of Cells

Object: To determine the internal resistance of a cell (a) by Ohm's law method, (b) by the reduced deflection method.

Reference: "Modern Physics," Section 556.

Apparatus: A Daniell or gravity cell, voltmeter and ammeter, both graduated in tenths, knife-switch, resistance box, dry cell.

Procedure: Connect the gravity of Daniell cell in series with a switch, ammeter and resistance box. Connect a voltmeter across the terminals of the cell. See Fig. 605, p. 442 of textbook.

With the switch open read the voltmeter. Record this reading as E volts.

Since this cell has a high internal resistance, it is not necessary to put any other resistance in the external circuit. The re-

sistance box may therefore be set at zero and the switch closed. Read the voltmeter and ammeter. Record the ammeter reading (I), and the voltmeter reading (E).

Calculate the resistance of the cell by applying Ohm's law as follows:

$$r=\frac{E—E_1}{I}$$

Repeat the experiment with the dry cell in place of the Daniell cell. In this case a small resistance must be introduced in the resistance box before closing the switch.

Note: The current from a dry cell is too heavy to be put through the ammeter without some resistance in the circuit. **Do not burn out your ammeter.** Have your teacher check your apparatus before proceeding.

(b) **Reduced deflection method.** Connect the Daniell cell, switch, ammeter and the resistance box in series. With a zero resistance in the resistance box, close the switch and take the ammeter reading. Record this. Now remove plugs from the resistance box until enough resistance has been introduced to reduce the ammeter reading to exactly one-half. Record the resistance of the resistance box. This is a measure of the internal resistance of the cell.

Repeat the experiment using the dry cell, only in this case connect a low resistance shunt across the terminals of the ammeter. Remember your ammeter is a valuable instrument. Protect it from an overload.

Results: Tabulate all results as follows:

Type of cell used	E	E_1	I	Ext. Res. R	Int. Res. r

Compare the results as given by the two methods. Which is more accurate? Give reasons.

EXPERIMENT 17

Magnetic Field about a Conductor

Object: To perform Oersted's experiment and to study the nature of the magnetic field about a wire carrying a current.

Reference: "Modern Physics," Sections 561-564.

Apparatus: A galvanoscope having one turn, several turns and many turns, each with their respective binding posts, Pietenpol connectors, 3 dry cells or storage battery, Daniell cell, knife

switch, four small compasses, one large demonstration compass needle, sheet of stiff cardboard 1 ft. square, length of bare No. 12 or No. 14 copper wire.

Procedure: (a) Test Oersted's experiment as illustrated in Fig. 611 and Fig. 612, using the Daniell cell and a demonstration compass needle. Test the right-hand rule for determining the direction of the current. Place the wire above and below the needle and reverse the connections on the Daniell cell, testing the rule each time.

(b) Place the galvanoscope on the bench so that the single wire is parallel to the compass needle as it points towards the magnetic North pole. Turn the compass so as to bring the zero point directly below the North pole. Connect the Daniell cell with the knife switch in series with the terminals of the single galvanoscope wire so that when the switch is closed the current will flow from South to North over the needle.

Close the switch and note the direction in which the North pole is deflected and the number of degrees on the compass scale. Reverse the connections of the Daniell cell so that the current flows from North to South. Close the switch and read the number of degrees of the angle of deflection. Record these readings. Without changing the position of the galvanoscope on the bench, repeat the experiment with the compass needle under the few turns of wire. Record the angle of deflection for both directions of the current flow.

Repeat again with the many turns of wire. Record the angle of deflection of the needle.

(c) Pass the heavy copper wire through a hole in the sheet of cardboard, supporting the latter in a horizontal position by means of a wooden clamp. **Note:** An iron retort stand is frequently magnetized and may give erroneous results.

Connect the ends of the copper wire to three dry cells or a storage battery and the knife switch in series using No. 18 wire. Place the four small compass needles around the wire in the manner illustrated in Fig. 613 of the textbook.

Close the switch and observe the position of the compass needles. Reverse the connections so that the current flows in the opposite direction, close the switch and again observe the position of the needles. Apply right-hand rule No. 2 on p. 452 for both tests.

Results: Tabulate the results of experiment (b) and state the effect of increasing the number of turns of wire.

Draw diagrams to illustrate the positions of the compass needles in experiment (c): (i) when there is no current, (ii) when the current flows upward, (iii) when the current flows downward.

EXPERIMENT 18

Efficiency of Lamps

Object: To determine the efficiency of various lamps and to compare series and parallel wiring for lamps.

Reference: "Modern Physics," Sections 599 and 600.

Apparatus: A.C. voltmeter, 0-150; A.C. ammeter, 0-10; 3 40-watt lamps, 1 25-watt, 1 60-watt, 1 100-watt lamps; 16-c.p. and 32-c.p. lamps; a lamp board to be constructed as follows: On a piece of 3-ply wood, 6″ x 3′, set out three lamp sockets about 8″ apart and towards one end of the board. Screw them to the board and connect them, in parallel (Fig. 654), with a heavy insulated electrician's wire. Remove only enough of the insulation to make good contact on the sockets. Spread the rest of the wire along the board and fasten the ends to two terminal binding posts, well insulated, at the extreme end of the board. On one wire insert a lamp socket to take a fuse plug and a single-pole-single-throw porcelain based knife switch. Cut the wire at two points equally spaced between the terminal post and the first lamp socket, and insert the fuse socket and the knife switch in series with each other. On the other wire insert another lamp socket to take a second fuse plug and two binding posts for attaching an ammeter. You should now have in series going from one binding post to the other, a lamp socket (A), a knife switch, a group of three lamps (B, C and D) in parallel, two binding posts (M and N), and another lamp socket (E).

Procedure: (a) Connect the terminals of the lamp board to an A.C. 110-volt outlet by means of a lamp cord and plug. Insert two 6-ampere fuse plugs in sockets A and E. These are to protect the measuring instruments.

Place a 25-watt lamp in socket B. Connect an ammeter across M and N and a voltmeter across the terminals of the lamp B. Close the switch and read the ammeter and voltmeter. Record the readings in a table as shown below.

Do the same for the 40-watt, the 60-watt, the 100-watt, the 16-c.p. carbon and the 32-c.p. carbon lamps.

Record all readings. **Note:** Open the knife switch each time you replace a lamp in socket B.

(b) Place a 40-watt lamp in B. Take readings and record.

Place another 40-watt lamp of the same make in C.

Close the switch and read the ammeter and voltmeter.

Open the switch and transfer the voltmeter to the terminals of lamp C. Record readings.

Insert a third identical 40-watt lamp in socket D. Close the switch and read the ammeter and voltmeter, changing the latter to D after checking to see if there is any change in the reading at C. Record all readings.

(c) Remove the fuse plug nearest to the ammeter and insert a 40-watt lamp in its socket (E). Remove lamps from C and D. You now have lamps in B and E in series. Close the switch and determine the ammeter reading and the voltage across each lamp separately and across the two together. Record all readings.

Results: Tabulate the data of experiment (a) as follows, taking a 25-watt lamp to have a 20 c.p., a 40-watt lamp to have a 32 c.p., a 60-watt lamp to have a 50 c.p., and a 100-watt lamp to have 100 c.p.:

Kind of Lamp	Volts	Amps	Watts Used	Rated wattage	Candle Power	Watts per candle	Cost per candle per hour

Cost of electricity to be reckoned at 5c per kilowatt-hour.

Tabulate the results of experiments (b) and (c) thus:

No. of lamps	Connection	Voltage	Amperage
Single			
Two	Parallel		
Three	Parallel		
Two	Series		

What are the advantages of parallel wiring for lamps over series wiring?

EXPERIMENT 19

Induced Currents

Object: To study induced currents.

Reference: "Modern Physics," Sections 620-623 and 642.

Apparatus: Primary and secondary coils with core, or Gilley's induction study outfit, or home-made coils as in figure 718 of text; bar magnet small enough to enter larger coil, sensitive galvanometer, dry cell.

Procedure: (a) Connect the larger coil to the galvanometer. Hold the magnet about six inches away from the coil with the north pole nearer to it. Thrust the magnet quickly into the coil, hold it there a moment, pull it out. Note the direction of any deflection of the galvanometer needle. Work out the direction of flow of the currents in the coil. Work out the polarity of the end of the coil nearer the magnet for each current.

Repeat using the South pole of the magnet.

Record your results as follows:

Magnet movement	Deflection of needle (right or left)	Direction of current in coil. (Clockwise or counter clockwise in face nearer the magnet)	Polarity of coil face nearer magnet
N Pole Toward coil			
Stationary in coil			
Away from coil			
S Pole as above			

(b) Connect a dry cell to the smaller coil. Use this coil in the same manner as you did the magnet in (a), pushing it in and out of the larger coil. Note the movements of the galvanometer needle.

Repeat with the core in the smaller coil.

Repeat with the current reversed.

Record in a manner similar to that used in (a), showing in the last column whether the induced current is in the same or the opposite direction to the current in the primary.

What was the effect of putting the core in the smaller coil?

Does the induced current always oppose the primary current?

(c) Disconnect one wire from the cell. Place the smaller coil inside the larger. Touch the disconnected wire to its binding post; remove it after holding it there a moment. Note any movement of the galvanometer needle while the circuit is being closed and opened. Repeat with the core in the smaller coil.

Record your results as in (a) and (b).

Does any current flow in the secondary while a current flows steadily in the primary?

Which induces the larger current, making or breaking a circuit?

What is the effect of the core?

Does the induced current always oppose the change which causes it?

EXPERIMENT 20

The Electric Motor

Object: To study the action of a simple electric motor.

Reference: "Modern Physics," Sections 635-640.

Apparatus: St. Louis type demonstration motor, dry cell.

Procedure: Remove the bar magnets from their holders and connect the dry cell to the armature terminals. Turn the armature by hand through a complete circle and test the polarity of each end of the armature by means of a bar magnet (law of magnetic poles) at several points in the circle. Note the change in polarity as the two segments of the commutator move from one brush to the other. Draw diagrams as in Figs. 708-710, p. 508 of textbook, and indicate the polarity in different positions.

Now insert the bar magnets so that a North pole of one and a South pole of the other are close to the armature. Connect the dry cell as before and set the armature rotating.

Study the effect of separating the magnets further apart on the speed of the motor, and the effect of using two like poles. Reverse the connections of the dry cell. Note the direction of rotation of the motor. Now disconnect the dry cell, remove the bar magnets and insert the electro magnet. Connect the dry cell, the armature terminals and the field magnet all in series. Note the direction of rotation of the armature. Change the connections on the dry cell so as to reverse the direction of the current. Note the direction of rotation now. Is there any change? Why is this different from the effect with permanent field magnets?

Now connect the armature, the field magnet and the dry cell in parallel. Again try the effect of changing the connections on the dry cell so as to reverse the direction of the current. How does this affect the direction of rotation of the motor?

Results: Draw diagrams to show the connections, the direction of current flow and direction of rotation, also polarity of the field magnets for each of the three types used, i.e., (i) using permanent field magnets, (ii) series wound motor, (iii) shunt wound motor.

CHEMISTRY 2

DIRECTIONS TO STUDENTS

1. Before coming into the laboratory to perform an experiment, study the directions outlined here in the procedure. Be sure that you understand what you will be doing, and why. Do not attempt an experiment the relevant theory, of which you have not already studied.
2. Question each step as you proceed. Learn the names of the chemicals and apparatus. Examine materials used; and also the precipitates formed, and other products, so as to be able to identify them as your work progresses.
3. Follow the directions closely and use great care when flames, acids, and bases, and inflammable liquids are employed.
4. Use small quantities of chemicals. Larger quantities frequently retard the progress of the experiment.
5. Record all results of your experiment and make liberal use of diagrams (sectional) in making your report. These diagrams should be neatly drawn and neatly labelled.
6. Be sure your apparatus is clean. After completion of the experiment, clean all apparatus and leave the desk in a dry and tidy condition.
7. Learn the capacity (in cc.) of an ordinary test tube so as to be able to measure out approximate volumes (10 cc.) without loss of time.
8. In case of accident, call your instructor at once.

In the following exercises—

"Result?" means to make a written record of your observation.

Interpret "Odour?" "Equation?" also in written form.

Unless the word "dilute" is used before an acid, the concentrated acid is to be used.

Bracketed numbers refer to related material in the authorized textbook.

LIST OF EQUIPMENT: CHEMISTRY 2

This list makes adequate provision for practical work. At the present time, however, it may be difficult to get some of the apparatus and materials listed; and it may be necessary for instructors to improvise equipment and substitute other materials.

SUPPLIES FOR SIX STUDENTS

The following is a list of the supplies needed for six students working in three groups of two each or for three students working singly. A reasonable margin has been allowed for breakages. It includes several pieces of equipment which are also re-

quired for Chemistry 1. The list is divided under sub-headings as follows:

A.—Apparatus required for all groups. It is desirable that this be issued at the beginning of the year, especially if drawers and cupboards lock.

B.—(1) Apparatus for common use of several groups. This should be considered a minimum list.

(2) Additional and more extensive apparatus which should be included for large classes or even for small ones if circumstances permit.

C.—Chemicals.

D.—Materials which may be obtained locally.

A.—Apparatus required for all groups.

(Quantities are sufficient for three groups.)

Note: "Pyrex" or some good resistance glass is recommneded for all glassware. Although it is more expensive, it is so much more durable that its use results in greater economy being effected.

DESCRIPTION	QUANTITY	
Alcohol lamps, 4 oz. at least (or bunsen burners with the fish tail attachments if gas is available)	3	
Beakers, low form with lip, 250 cc.	6	
Beakers, low form with lip, 150 cc.	6	
Blowpipes, 8-10 inches, brass recommended	3	
Blue Glasses, 2″ x 1″	3	
Bottles for collection of gases, etc., at least 8 oz., low form	12	
Bottles for reagents, glass stoppers, at least 4 oz.	30	
Burettes, 50 cc., Mohr type for pinchcock recommended	3	
Burette, fittings for above, burette tip with rubber tubing and pinchcock	3	
Filter papers, 5″ in dia., coarse for rapid work	1	pkg.
Flasks, Erlenmeyer, 300 cc., No. 6 top	4	
Rubber stoppers, two holes, No. 6 for the above flasks	4	
Funnels, glass, 65 mm. dia., 150 mm. stem	3	
Glass tubing, 6 mm., ext. dia.	1/8	lb.
Graduates, 100 cc. to show 1 cc.	3	
Graduates, 10 cc.	3	
Non-combustible rods for flame tests (or see B list)	3	
Pipettes, 10 cc., (Note: 3 burettes may be used instead)	1	
Pneumatic troughs, galvanized iron or glass, about 7″ x 10″ x 5″	3	
Retorts, 125 to 250 cc., glass for making bromine	3	

Description	Quantity
Retort stands, base, about 3½" x 6½"	3
Retort stands, rings—large 3¼" dia. inside; small, 2½" dia.	3 each
Retort stands, fixtures, burette clamp	3
Rubber tubing, 3/16" dia. inside for generators and connections	8 ft.
Test Tubes, 16 mm. dia. outside, 150 mm. long	30
Test Tubes, 20 mm. dia. outside, 150 mm. long (prep. of O_2)	5
Rubber stoppers, 1 hole, size No. 2, large end, 20 mm.	3
Test Tube brush, bristle end	3
Test Tube racks, large enough to hold 10 tubes upright rec.	3
Thistle tube, stem, 6 mm. dia. outside	4
Tubes, combustion, dia. inside, about 15 mm., length 5-12"	3
Wire gauze squares, iron or copper, 4" side	3

B.—(1) Apparatus for the common use of several groups.

Description	Quantity
Balance, with weights, capacity, 100 to 150 grams, sensitivity, 5 mg. (Note: If balance is to be used for Physics 2 as well, one of greater capacity should be obtained)	1
Bottles, reagent, glass stoppers, 500 cc. capacity	10
Beaker, low form with lip, pyrex, capacity, 600 cc.	1
Barometer, graduated in Metric scale, aneroid is recommended	1
Files, triangular, 5"	3
Funnel, glass, dia. at least 80-100 mm.	1
Mortar and pestle, about 5 inches in dia.	1
Thermometer, Centigrade, range, —10° —110°, solid stem	1
Platinum wire, length 3" long sealed in glass tubing	6 in.
Flask, Erlenmeyer, 500 cc., with generator fittings if Kipp's Apparatus is not available (See below)	1

Furniture: (1) Tables for students' practical work in the laboratory. Suggestions re. construction: height, 36 inches; width, 4 ft.; length, depends on requirements and space available. Each group needs a space about four feet wide and half the width of the table; this gives about eight square feet. A shelf along the centre of the table is convenient for reagent bottles. Drawer and cupboard space for storing apparatus in students' tables is needed and should be added when finances will permit. If they are constructed with

locks, groups may be given sets of apparatus at the beginning of the year and held responsible for it throughout the year. (2) Cupboards, which will lock, are needed for storing chemicals and apparatus. (3) Demonstration table for instructor, specifications, see above, width 2½ to 4 ft.

B.—(2) Additional and more extensive apparatus which should be included for large classes.

Kipp's gas generator, capacity of generating chamber, 500 cc. 1

Fume cupboard: As poisonous gases are very injurious for students and teacher, a fume cupboard for the preparation of such gases should be provided. Position, near demonstration table in the classroom so that it may be used conveniently during instruction periods, as well as during laboratory periods.

Size, at least two feet square; bottom of cupboard, 3 feet from floor; height, about 3½ feet, that is, top, 6½ feet from floor.

Ventilation: If poisonous gases are to be prevented from entering the room, this cupboard should be connected to the outside of the building by means of a pipe. If it is not feasible to do this through the heating or ventilating systems of the building, an electric fan may be found to be effective.

NOTE: Large classes will require additional quantities of the apparatus listed under B (1) above.

C.—CHEMICALS.

(For class of six, i.e., three groups.)

NOTE: Even for classes as small as six, it will be found to be more economical to buy in larger quantities than those given below.

Description	Quantity
Alcohol (for use in lamps)	1 pt.
Alcohol, denatured	1 qt.
Alum, pure powder	1 lb.
Aluminium foil or turnings	2 oz.
Aluminium Chloride C.P.	1 oz.
Aluminium Nitrate C.P.	4 oz.
Aluminium Sulphate C.P.	2 oz.
Ammonium Carbonate C.P.	4 oz.
Ammonium Chloride C.P.	1 oz.
Ammonium Hydroxide C.P.	1 oz.
Ammonium Nitrate C.P.	4 oz.

Description	Quantity
Ammonium Molybdate C.P.	1 oz.
Ammonium Sulphate C.P.	4 oz.
Ammonium Sulphide Solution	4 oz.
Ammonium Sulphite C.P.	4 oz.
Ammonium Phosphate C.P.	4 oz.
Ammonium Thiocyanate C.P.	2 oz.
Arsenious Oxide (Demon. only)	1 oz.
Barium Chloride C.P.	4 oz.
Barium Nitrate C.P.	4 oz.
Bismuth Trichloride	1 oz.
Bleaching Powder	12 oz.
Borax, crystals	1 lb.
Calcium Carbonate, ppt.	4 oz.
Calcium Carbonate, marble chips	1 lb.
Calcium Chloride C.P.	4 oz.
Calcium Hydroxide, Tech.	1 lb.
Calcium Nitrate C.P.	1 oz.
Carbondisulphide	1 lb.
Carbontetrachloride	1 lb.
Charcoal, animal, powder	4 oz.
Charcoal, lumps or blocks	1 oz.
Chloroform, Tech.	1 oz.
Cobalt Nitrate	1 oz.
Copper filings	4 oz.
Cupric Bromide	1 oz.
Cupric Nitrate C.P.	4 oz.
Cupric Sulphate, C.P., pow.	½ lb.
Cupric Sulphate, Tech.	½ lb.
Cupric Chloride, C.P.	4 oz.
Ferric Chloride, C.P.	4 oz.
Ferric Nitrate, C.P.	4 oz.
Ferric Sulphate, C.P.	4 oz.
Ferrous Chloride, C.P.	4 oz.
Ferrous Sulphate	4 oz.
Ferrous Sulphide, granular	8 oz.
Glucose, pure anhydrous	4 oz.
Hydrochloric Acid, C.P.	1 lb.
Iron filings	1 lb.
Lead Nitrate, C.P.	4 oz.
Lead Peroxide, Tech.	1 oz.
Lead Oxide (litharge)	4 oz.
Lead Oxide (red lead)	1 oz.
Lithium Chloride	1 oz.
Litmus, Best qual., gran.	1 oz.
Litmus paper, blue, vial of 100 strips	
Litmus paper, red	
Magnesium ribbon	1 oz.
Magnesium Carbonate, heavy	4 oz.
Magnesium Chloride, C.P.	4 oz.
Magnesium Nitrate, C.P.	4 oz.

Description	Quantity
Magnesium Sulphate, C.P.	8 oz.
Manganese Dioxide, C.P.	4 oz.
Manganese Dioxide, Tech.	1 lb.
Mercury metal	1 oz.
Mercuric Chloride, C.P.	1 oz.
Mercuric Nitrate, C.P.	1 oz.
Mercurous Nitrate, C.P.	1 oz.
Methyl Orange	½ oz.
Nitric Acid, C.P.	1 lb.
Nickel Chloride	1 oz.
Phenolphthalein	1 oz.
Portland Cement	4 oz.
Potassium Bromide, C.C. or U.S.P.	4 oz.
Potassium Carbonate, C.P.	4 oz.
Potassium Chlorate, C.P., pow.	4 oz.
Potassium Chloride, C.P.	4 oz.
Potassium Chromate, C.P.	4 oz.
Potassium Ferricyanide, C.P.	1 oz.
Potassium Ferrocyanide, C.P.	4 oz.
Potassium Iodide	1 oz.
Potassium Nitrate, C.P.	4 oz.
Potassium Permanganate U.S.P.	4 oz.
Potassium Phosphate, C.P.	4 oz.
Potassium Sulphate, C.P.	4 oz.
Potassium Sulphite, C.P.	4 oz.
Silver Nitrate	1 oz.
Sodium Acetate Anhy.	1 lb.
Sodium Bicarbonate, C.P.	1 lb.
Sodium Carbonate, Tech., pow.	8 oz.
Sodium Chloride, C.P.	1 lb.
Sodium Hydroxide, C.C. sticks or pellets	4 oz.
Sodium Nitrate, C.P., pow.	1 lb.
Sodium Peroxide, pow.	4 oz.
Sodium (Disodium) Phosphate, C.P.	4 oz.
Sodium Sulphate, C.P.	4 oz.
Sodium Sulphite, C.P.	4 oz.
Sodium Sulphide, C.P.	4 oz.
Sodium Thiosulphate	4 oz.
Starch, corn	4 oz.
Strontium Chloride, C.P.	1 oz.
Sulphuric Acid, C.P.	1 lb
Zinc, C.P. (low in As.), gran.	1 lb.
Zinc Chloride, C.P.	2 oz.
Zinc Nitrate, C.P.	4 oz.
Zinc Sulphate, C.P.	4 oz.
Zinc Sulphide, Tech.	4 oz.

NOTE: The above list includes small quantities of a variety of salts which may be used as "unknowns" in Exercises 51 and 52.

Equivalents: 28.3 grams=1 oz.; 1 pound=453.6 grams.

D.—Materials which may be obtained locally.
(For class of six, three groups.)

Candles, paraffin, for demonstration	2
Clay, well pulverized	¼ lb.
Clock spring, 1/8″ wide	1 ft.
Commercial soap, 3 or 4 cakes.	
Copper sheet, medium gauge, 17 sq. in. cut into strips about 3″ x 3/8″.	
Zinc sheet or new galvanized iron, same as above.	
Distilled water	½ gal.
Finger bandaging, 2″ wide	1 yd.
Glass (window) cut in 3″ squares	6 squares
Honey	1 oz.
Iron nails, bright, 1½-2″	6
Lard or other fat	1 lb.
Lime (quicklime)	1 lb.
Molasses, black	2 oz.
Red calico	1/8 yd.
Sugar, cane or beet	28 gm.
Wooden splints—6″-8″ long	2 doz.
Oatmeal	1 oz.
Vegetable oil (olive, peanut, etc.)	1 oz.
Vinegar	1 oz.

LIST OF EXPERIMENTS

N.B.—References are made to chapters and pages of the Textbook.

1. BROMINE AND IODINE

(Chapter 10)

Bromine and iodine may be prepared by the students (p. 159), but it is suggested that these and chlorine water (p. 150) be prepared in advance by the teacher. Sodium salts may be substituted for potassium salts in this exercise.

Apparatus—Test tubes and rack. Burner.

Materials—Potassium chloride. Potassium bromide. Potassium iodide. Chlorine water. Bromine water. Silver nitrate solution. Ammonium hydroxide. Sulphuric acid (1 of acid to 2 of water). Manganese dioxide. Carbon disulphide or carbon tetrachloride. Alcohol. Iodine crystals. Starch. Tincture of iodine.

Tests for a chloride, a bromide and an iodide.

1. To a concentrated solution of each of (1) potassium bromide, (2) potassium iodide, in separate test tubes, add a few cc. of chlorine water (p. 162). Colours? Equations?

2. Half fill three test tubes with a dilute solution of a chloride, a bromide and an iodide, respectively. To each add a few drops of silver nitrate solution (p. 156). Colours? Equations?

3. After allowing the precipitate formed in (2) to settle, pour off the supernatant liquid. To each precipitate add about 5 cc. of ammonium hydroxide. Shake. Result?

4. Prepare a precipitate of silver chloride and let stand for a few minutes in a strong light. Result?

5. Into each of three test tubes pour about ½ cc. of sulphuric acid. (If not previously prepared by the teacher, this acid can be prepared by adding, slowly and carefully, 1 part of sulphuric acid to 2 parts of water). Into the first test tube pour about ½ cc. of a mixture of potassium chloride and manganese dioxide. To the second add a similar amount of a mixture of potassium bromide and manganese dioxide, and to the third add a mixture of potassium iodide and manganese dioxide. Warm each test tube gently if no reaction is visible (p. 159). Colours? Equations?

Solubility of halides.

6. Dissolve a pinch of (1) potassium bromide in 5 cc. of water, and of (2) potassium iodide in 5 cc. of water. To each add about 2 cc. of carbon disulphide or carbon tetrachloride. Shake and allow to stand. Now to each test tube add a little chlorine water and shake. Again allow to stand (p. 162). Result? Equations?

7. Into four test tubes put about 2 cc. of water, alcohol, carbon disulphide, potassium iodide solution, respectively. Drop a small crystal of iodine in each and shake (p. 162). Tabulate the colours and solubilities.

Test of iodine.

8. (a) To a solution of starch (obtained by boiling, if necessary,) add a few drops of tincture of iodine. Result?

(b) To a solution of potassium iodide add a little starch solution. Result? Now add to this solution chlorine water. Result?

9. Put a small crystal of iodine in a test tube. Heat. Result?

2. HYDROCHLORIC ACID

(Chapter 13)

Apparatus—Test tubes and rack. Beaker. Stirring rod. Burner. White Paper.

Material—Hydrochloric acid. Sodium hydroxide. A second acid. A second base. Litmus. Phenolphthalein. Methyl orange. Sulphuric acid. Potassium chloride.

1. Action of Indicators.

Half fill each of six test tubes with water. Number **1** to **6.** To numbers **1, 3** and **5** add a few drops of diluted hydrochloric acid, and to numbers **2, 4** and **6** pour a few drops of sodium hydroxide solution. Into **1** and **2** pour a few drops of litmus solution, into **3** and **4** a little phenolphthalein, and into **5** and **6** methyl orange. Repeat the experiment using a different acid and base (p. 218). Tabulate your results, as indicated below:

	Colour of Litmus	Colour of Phenolph-thalein	Colour of Methyl Orange
Hydrochloric acid			
Second acid			
Sodium hydroxide			
Second base			

2. Neutralization.

Into a beaker half full of water, add about 3 cc. of dilute sodium hydroxide solution. Add several drops of phenolphthalein. Stir. Place a sheet of white paper under the beaker. Now add slowly, while stirring, dilute hydrochloric acid till the colour **just** disappears. On the addition of a single drop of base the colour should begin to reappear. Explain. Equation? (See page 218.)

3. Test for hydrogen chloride.

Pour ½ cc. of concentrated sulphuric acid into a test tube and add a large pinch of potassium chloride. Warm gently and breath across the top of the tube. Result? (See page 221.)

(The fumes observed are due to the condensation of moisture in the breath, as it dissolves in the gas generated.)

4. Solubility of hydrogen chloride gas.

Put about 1 cc. of hydrochloric acid into a test tube fitted with a one-hole stopper in which is a piece of glass tubing about 3 inches long, open at both ends. Boil the acid till, on breathing over the end of the tubing, white fumes appear. Invert the test tube and quickly immerse the tubing in a beaker of water. Result?

3. SODIUM HYDROXIDE

(Chapter 14)

Apparatus—Test tubes and rack. Delivery tube. Collecting trough.

Materials—Caustic soda (sticks or pellets). Copper sulphate. Ferric chloride. Lead nitrate. Ferrous sulphate. Aluminum sulphate. Chalk or limestone. Ammonium chloride.

1. Properties.

Observe a **small** piece (¼ inch of stick) of caustic soda. (Do not handle.) Allow it to remain exposed to moist air for a few moments. Result? Drop the piece in about 2 cc. of water in a test tube. Note any change in temperature as it dissolves. Now dilute the solution with about 15 cc. of water. Rub a little of this solution between the finger and thumb. (Feel?) (See page 226.)

2. Precipitating reagent.

Into separate test tubes, pour about 10 cc. of each of the following solutions: copper sulphate, ferric chloride, lead nitrate, ferrous sulphate, aluminum sulphate. To each solution add a few drops of the basic solution prepared in (1). Results? Equations?

Now add an excess of the basic solution to each of the test tubes to see if the precipitate first formed dissolves. Results ?

3. Reaction with an anhydride.

Prepare a test tube of pure carbon dioxide. Invert it in a concentrated solution of caustic soda in a beaker, and allow to stand. Agitate a little if necessary to speed up reaction. Result? Equation? (See page 229.)

4. Test for ammonium radical.

Into a test tube place a pinch of ammonium chloride (or other ammonium salt). Add about 1 cc. of caustic soda solution and warm. Odour? Equation?

Repeat this experiment but use a few cc. of a solution of an ammonium salt instead of the solid as above. Result?

4. NEUTRALIZATION

(Chapter 14)

Apparatus—2 Burettes (50 cc.). Clamp. Stand. Beaker. Stirring rod.

Materials—Hydrochloric acid (1 of acid to 100 of water). Sodium hydroxide solution (1/10 Normal). Phenolphthalein.

1. Titration.

Set up two clean burettes (preferably 50 cc.) fitted with clamp or tap, on a stand. Fill burette A with hydrochloric acid (previously prepared by the teacher—1 of acid to 100 of water). Fill burette B with approximately .1 (=1/10) normal sodium hydroxide solution (previously prepared by the teacher). Run a little acid and base out of each burette into a beaker. Discard this liquid. Now make careful readings of the amount of acid and base in the burettes, by observing the position of the bottom of the meniscus, read at eye level. Record these readings.

Into the beaker run about 20 cc. of the acid. Add several drops of phenolphthalein solution. Keep a sheet of white paper under the beaker to aid in detecting colour changes. Place the beaker under burette B and run out about 10 cc. of the basic solution, stirring constantly. Continue to add the basic solution, **drop by drop,** stirring carefully. When the addition of a single drop of sodium hydroxide will produce a permanent pink colour, which disappears by the addition of a drop of the acid, the neutralization is complete. This titration is said to have reached the "end point."

Take the readings from the burettes. Calculate the volume normal, calculate the weight of hydrogen chloride in 1 liter of solution used. Calculate also to 2 decimal places the normality of the acid solution, using the formula

$$V_A \times N_A = V_B \times N_B$$

when V = volume
N = normality
A = acid
B = base

(V_A would read "Volume of acid".)

5. IONIZATION

(Chapter 16)

Apparatus—Glass plate. Test tubes and rack.

Materials—Tartaric or oxalic acid. Slaked lime. Litmus. Several salts.

1. Effect of moisture on acid and basic reactions.

Place a clean, dry glass plate on a sheet of white paper. On the plate place separately a pinch of dry tartaric or oxalic acid, and a little slaked lime. Test the acid and lime with separate pieces of dry red and blue litmus. Result?

Now moisten each of these substances with a drop or two of water. Again test with the litmus papers. Results? Explanation?

2. Effect of dilution upon ionization.

Into each of 3 dry test tubes put a small quantity (about 1 cc.) of copper sulphate (powdered), copper chloride and copper bromide, respectively. In this exercise observe carefully for colour changes. To each test tube add **one** or **two drops** of water, then slowly add more water till no further colour change occurs. The final colour should be a light blue. Tabulate your results in the following form:

Salt	Formula	COLOUR WHEN			
		Dry	Moist	Concentrated solution	Dilute solution
Copper sulphate					
Copper chloride					
Copper bromide					

Write equations indicating the ionization.

3. Reversible reaction.

To a solution of sodium carbonate in a test tube, add some potassium nitrate solution. Any reaction? Explain. Equation?

Into a beaker put about 1 grain of bismuth trichloride. Add a drop or two of hydrochloric acid. If necessary add a little more, just enough to dissolve the salt. Now add water slowly, stirring constantly till a definite change occurs. Result? The equation for the reaction is

$$BiCl_3 + H_2O \rightleftharpoons BiOCl + 2\,HCl.$$

The bismuth oxychloride is insoluble.

Now add dilute hydrochloric acid till the reaction is completely reversed.

4. Common ion effect.

Make a **strong** solution of sodium chloride in water, in a test tube, and then add about an equal amount of hydrochloric acid. What happens? Can you account for the result?

6. HYDROLYSIS

(Chapter 16)

Apparatus—Test tubes and racks.

Materials—Litmus. Several salts.

1. Litmus reactions on solutions of salts.

Into separate test tubes put a pinch of each of the following salts: sodium chloride, ferric chloride, copper sulphate, potassium nitrate, sodium carbonate, ammonium sulphate, sodium borate (borax). To each test tube add about 5 cc. of water and shake. Drop a small piece of red and of blue litmus into each solution. Examine the litmus. (See page 260.)

Tabulate your results as indicated below:

Name of salt	Formula	Effect on litmus	Acid Basic or Neutral	Hydrogen ion concent'n	Hydroxyl ion concent'n	Salt of
Potassium carbonate	K_2CO_3	Red to blue	Basic	Low	High	Weak acid Strong base
Sodium Chloride						

2. Write an equation for each of the above reactions which did not show a neutral effect on litmus. (See page 261.)

3. Write an ionic equation corresponding to each equation in (2).

7. FLAME TESTS

(Chapter 25)

Apparatus—Platinum (or nichrome) wires. Burner. Cobalt glass.

Material—Salts of sodium, potassium, lithium, calcium, barium, strontium, copper. Dilute hydrochloric acid.

For this experiment it is desirable to have a platinum wire for use with each salt tested. In this case, the glass tube (in the end of which the platinum wire is held) should be inserted through a one-hole stopper. This stopper is then inserted into the test tube, and the test tube labelled with the name of the solution it contains. The wire should reach into the liquid. Since this arrangement makes it possible to test only this one salt on this wire, time need not be lost in cleaning the wire after every test. If separate wires are not available, the platinum wire may be cleaned after testing a salt by alternately dipping it into a

little clean dilute hydrochloric acid, and heating, until all trace of the colour of the salt tested has disappeared.

Test—Remove the wire from the solution in the test tube and hold it at the edge of a colourless flame. Colour? Repeat several times. Observe flames of the following salts through a cobalt glass in addition to the regular tests: Sodium, potassium, a mixture of sodium and potassium (p. 403). Put the corner of a copper wire gauze into a little dilute hydrochloric acid and hold in a colourless flame. Result? Powder a little blackboard chalk and apply the flame test. Colour? Clean the wire thoroughly (if necessary) at the end of each test.

A salt of strontium may be tested if desired.

Record your results in the following form:

Element	Formula of Compound	Colour of Flame	Colour through Cobalt glass	Sample of Colour

8. ALUMINUM

(Chapter 26)

Apparatus—Test tubes and racks. Burner. Beakers (2). Blow pipe.

Materials—Aluminum foil. Hydrochloric acid. Sodium hydroxide solution. Splint. Aluminum sulphate. Ammonium hydroxide. Lime water. Charcoal block. Cobalt nitrate solution. Cotton cloth. Logwood.

1. Action of strong acid and base

Into each of two test tubes put about 1 sq. cm. of aluminum foil. To one add about 2 cc. of hydrochloric acid (concentrated),

and to the other some caustic soda solution. Warm gently for a few moments. Results? Equations?

Test any gas that is generated, with a burning splint. Result? (See page 415.)

2. Action of caustic soda on aluminum hydroxide.

Half fill each of two test tubes with a solution of aluminum sulphate. To the first add a few drops of ammonium hydroxide solution, then several cc. Result? Equation?

To the second add a little caustic soda solution, then an excess. Result? Equations?

3. Purification of water by aluminum hydroxide.

Prepare some murky water by stirring a handful of soil in water. Allow the mixture to stand a few minutes. Then pour off some of the cloudy water into each of two beakers. To one add about 2 cc. of alum solution or solution of aluminum sulphate, and then several cc. of lime water. Allow to stand and observe at five minute intervals. The second serves as a control for purposes of comparison. Results? Equation? (See page 420.)

4. Test for aluminum ion.

Using a small coin, wear a depression near one end of a charcoal block. Fill this with some aluminum compound (moistened to a paste) and heat with the oxidizing flame of a blowpipe. Moisten the residue with a few drops of cobalt nitrate solution. Heat strongly again. A blue colour indicates aluminum.

5. Aluminum hydroxide as a mordant.

Cut two pieces of white cotton cloth. Mordant one by soaking it in a solution of aluminum sulphate and then in ammonium hydroxide, squeezing out the excess liquid after each soaking. Now place both pieces of cloth in a beaker containing logwood or alizarin solution. Boil for a few minutes. Wash the cloths and examine. Results? Equation? (See page 635.)

9. COPPER

(Chapter 28)

Apparatus—Test tubes and racks.

Material—Several salts. Nail. Potassium ferrocyanide. Ammonium hydroxide. Copper strip. Silver nitrate solution. An iron salt.

1. Colour of cupric ion.

Dissolve, in separate test tubes, small quantities of copper sulphate, copper chloride, copper bromide, sodium chloride and potassium nitrate. Colours?

Write ionization equation for each of the above and state the colour of each ion formed. (See page 459.)

2. Tests for copper ion.

Place a clean nail in a solution of copper sulphate. Allow to stand. Result?

Add some potassium ferrocyanide solution to a dilute solution of copper sulphate. Result? Equation?

Add ammonium hydroxide solution, drop by drop, to a solution of copper sulphate, till no further change occurs. Results? Equations? (See page 459.)

Suspend a strip of copper in silver nitrate solution in a test tube. Observe frequently. Results? Equation?

Try another strip of copper in a solution of an iron salt. Result? (See page 396.)

10. ZINC AND SILVER

(Chapter 29)

Apparatus—Charcoal block, blow pipe, beaker.

Materials—Hydrochloric acid, zinc pellet, nail, sodium carbonate, aluminum foil, badly tarnished piece of silverware, silver ring or dime.

1. Galvanizing—(This section of the experiment is optional.)

Scoop a hole in the charcoal block and place zinc pellet in the depression.

Take the nail and dip it into the concentrated hydrochloric acid. Why? Explain. (See page 220.)

Heat the zinc pellet using the blowpipe and, while the zinc is molten, thrust the nail into it. What do you notice after the nail is removed? Explain. (See page 467.)

2. Cleaning Silverware.

Make a solution of sodium carbonate (10 grams of sodium carbonate in about 100 cc. of water). Heat the solution to boiling point. Place the aluminum foil in the bottom of the beaker and the tarnished silver article in contact with the foil. Heat the beaker for a period of twenty minutes or longer. Remove the article, wash and dry.

What do you notice? Explain, writing the necessary equations. (See page 469.)

11. BAKING POWDERS

(Chapter 30)

Apparatus—Test tubes and racks. Stand. Clamp. Delivery tube. Burner. Beakers (250 cc.).

Materials—Baking soda. Lime water. Cream of tartar. Dilute hydrochloric acid.

1. Action of heat on baking soda.

Put about 2 grams of bicarbonate of soda in a test tube and

support this in an almost horizontal position on a stand. Arrange a delivery tube so that it leads into lime water in a test tube. Heat the bicarbonate gently. Result? Equation? (See page 503.)

2. Action of a strong acid on baking soda.

Into a test tube put a small quantity of sodium bicarbonate. Have a stopper and delivery tube arranged as in part (1). Add a few drops of dilute hydrochloric acid to the salt and replace the stopper quickly. Result? Equation? (See page 366.)

3. Reaction of a baking powder.

Weigh out 2 gm. of potassium bitartrate (cream of tartar). Calculate the weight of sodium bicarbonate needed to react with it (p. 365). Weigh out this quantity and mix the two salts. Put half the mixture into a beaker containing 100 cc. of cold water, and the other half into 100 cc. of hot water. Results? Equations?

12. CALCIUM COMPOUNDS

(Chapter 31)

Apparatus—Test tubes and racks. Wire gauze. Burner. Evaporating dish. Broken test tubes.

Materials—Chalk. Litmus. Plaster of Paris. Quick lime. Sand. Portland cement. Hydrochloric acid. Lime water.

1. Lime.

Place a piece of marble or chalk about the size of a pea on a wire and heat strongly for 20 minutes. Allow to cool. Now put it in a test tube and add a little water. Note any temperature change. Test with red and blue litmus. Result? Equation? (See page 511.)

2. Plaster of Paris.

Put a heaping tablespoonful of Plaster of Paris in an evaporating dish. Add just enough water to make a thick paste. When hardened to the proper consistency, mould rapidly into any desired shape. Allow to harden. Equation? (See page 516.)

3. Mortar.

Mix together small quantities of quicklime and sand in the proportions of 1 to 2 by volume. Add water to make a thick paste. Pour into a broken (useless) test tube and allow to stand for a week. Break away the test tube and examine. Result? (See page 515.)

4. Cement.

Mix some Portland cement and fine sand in the proportions of 1 to 3 by volume. Add enough water to make a thick paste. Pour into a broken test tube or paper box and allow several days to harden. Result? (See page 551.)

5. Hard water.

Pass carbon dioxide (prepared by the action of an acid on a carbonate) into lime water till the precipitate at first formed clears. Equations? Now boil some of this clear water. Result? Equation? (See page 521.)

13. COMPOUNDS OF IRON

(Chapter 32)

Apparatus—Test tubes and rack. Burner.

Materials—Ferric salts. Ferrous salts. Sodium hydroxide. Ammonium thiocyanate. Potassium ferrocyanide. Potassium ferricyanide. Nitric acid. Dilute sulphuric acid. Steel wool. Dilute hydrochloric acid.

1. Tests for a ferrous salt.

Half fill each of four test tubes with a dilute solution of a ferrous salt (freshly prepared). Into the test tubes put, respectively, a few drops of the following solutions: Sodium hydroxide, ammonium thiocyanate, potassium ferrocyanide, and potassium ferricyanide. Colours? Equations? (See page 529.)

2. Tests for a ferric salt.

Repeat the procedure outlined in (1) but use a ferric salt instead of a ferrous salt in the original test tubes. Colours? Equations?

Tabulate the results of (1) and (2) in the form shown below, giving the name of the salt formed, its formula and its colour. Indicate any precipitates formed by an arrow (pointing downward).

	Ferrous salt	Ferric salt
Sodium hydroxide $NaOH$		
Ammonium thiocyanate NH_4CNS		
Potassium ferrocyanide $K_4Fe(CN)_6$		
Potassium ferricyanide $K_3Fe(CN)_6$		

3. Oxidizing a ferrous salt.

To 5 cc. of a solution of ferrous sulphate, add 1 cc. of dilute sulphuric acid, and then a few drops of nitric acid (concentrated). Boil (CAUTION!). Test a small quantity of the resulting liquid for ferrous and ferric ions. Result? Equations? (See page 527.) (Ferrous chloride and chlorine may be substituted for ferrous sulphate, nitric acid and sulphuric acid in this experiment.)

4. Reducing a ferric salt.

To 10 cc. of a solution of ferric chloride add several strands of steel wool (or mossy zinc). Pour in 2 or 3 cc. of dilute hydrochloric acid. Warm gently. Test small quantities of the solution from time to time for ferrous and ferric ions. Result? Equation? (See page 527.)

14. METHANE

(Chapter 34)

Apparatus—Large pyrex test tube, outlet tube, stoppers, gas jars, pneumatic trough, mortar and pestle.

Materials—8 gm. anhydrous sodium acetate, 10 gm. soda-lime, dilute solution of potassium permanganate.

1. Preparation of Methane.

Mix THOROUGHLY in a mortar, 8 gm. of anhydrous (fused) sodium acetate and 10 gm. of soda-lime. Introduce the mixture into a large pyrex test tube and attach a glass outlet tube.

Heat the test tube gently, at first, and then more strongly until an evolution of gas takes place. After the air in the test tube has been displaced, collect (over water) several jars of the gas.

Calculate how many cc. of methane (under S.T.P. See note page 32) should theoretically be obtainable from 8 gm. of sodium acetate.

Write the equation for the reaction.

2. Properties of Methane.

Test methane for inflammability by applying a flame to the mouth of one of the jars of the gas. Explain the lack of luminosity to the flame.

Allow the gas to bubble into one of the gas jars until it is one-tenth full of the gas. Keep the jar inverted and permit the air to fill the remaining part. Apply a flame to the mouth of the jar containing the methane-air mixture. Why is the action rapid in this case? Write the equation for the reaction and calculate how much air (20 per cent oxygen) would be required to oxidize 10 cc. of methane.

Shake a few cc. of a .3% solution of potassium permanganate in a jar of methane gas. Note whether the permanganate solution changes colour. If the methane gas as prepared, contains small amounts of easily oxidized impurities, what effects may they have on this test?

15. DETERMINATION OF ACIDITY OF VINEGAR

(Chapter 35)

Apparatus—Burette (50 cc.) Pipette (10 cc.) Ring standard clamp, beaker (250 cc.).

Materials—Vinegar or cider. Distilled water. O.IN solution of sodium hydroxide. Phenolphthalein solution.

(For this experiment a O.IN solution of sodium hydroxide should be prepared in advance as follows: Dissolve 4 grams of caustic soda in distilled water. Dilute to 1 liter. Stir well.)

Using the pipette, put exactly 10 cc. of the vinegar (or cider) into a beaker. Add about 50 cc. of water. Add a few drops of

phenolphthalein. Fill the burette with the sodium hydroxide solution and titrate by running the basic solution into the beaker, drop by drop, till the end point is reached (as in exp. 4). Record the volume of base used (final reading minus first reading in the burette).

Repeat the titration and again record the volume of base used.

Calculations:

Concentration of sodium hydroxide solution ..... O.IN
Volume of basic solution used:
first titration ....cc.
second titration ....cc.
average ....cc.
Normality of vinegar .....
Calculate the normality of vinegar, using the formula:
Va x Na = Vb x Nb.

16. SOAP

(Chapter 35)

Apparatus—Beakers, evaporating dish, ring and stand, wire gauze, cheesecloth.

Materials—12 gm. of lard or other fat, 25 cc. denatured alcohol, 3 gm. of sodium hydroxide, 3 or 4 brands of commercial soap.

1. Manufacture of soap.

Weigh 12 gm. of lard or other fat. Place it in a beaker and add 12 cc. of alcohol, and 3 gm. of sodium hydroxide dissolved in 12 cc. of water.

Set the beaker in a second larger beaker containing hot water. Stir the mixture frequently and continue heating for an hour.

After this, add 100 cc. of a saturated salt solution. Cool the mixture and filter it through a double thickness of cheesecloth. Rinse the soap in the filter with 50 cc. of cold water. Press the soap in a small dish which will serve as a mold.

2. Some properties of certain soap solutions.

Dissolve small chips of commercial soaps in different beakers, using 10 cc. of water.

To each, add a small amount of phenolphthalein.

Result? Explain.

Compare degrees of alkalinity.

Should soaps be strongly alkaline? Explain.

3. Insoluble soaps.

Test the reaction of a soap solution with solutions of copper sulfate, magnesium sulfate, zinc chloride, calcium chloride.

Results? Equations?

What salts are present in hard water? Name some insoluble soaps and give their uses.

4. Emulsifying Power of Soap.

Shake 3 or 4 drops of cotton seed oil, corn oil or olive oil with 10 cc. of a solution of soap. Is an emulsion produced?

Explain how soap cleans.

17. FOOD INGREDIENTS

(Chapter 36)

Apparatus—Test tubes and rack. Burner. Mortar and pestle. Porcelain crucible cover.

Materials—Starch. Glucose. Cane Sugar. Fat. Oil. Egg. Oatmeal. Cheese. Iodine solution. Fehling's solution. Hydrochloric acid. Sodium carbonate. Litmus. Benzene. Nitric acid (conc.). Ammonium hydroxide.

1. Test for starch.

Put a pinch of starch in a test tube. Half fill with water. Shake and boil. Cool and add a drop of iodine solution (diluted tincture of iodine in potassium iodide solution). Colour? (See page 602). Test freshly cut pieces of potato and bread with iodine solution.

2. Test for sugar.

Dissolve 1 cc. of glucose in 10 cc. of water. Add 5 cc. of Fehling's solution and boil for a few minutes. The red precipitate formed is a test for glucose or fructose. (See page 603.)

Repeat using a solution of cane sugar (sucrose). Result? Now add a few drops of dilute hydrochloric acid to a solution of cane sugar in a test tube. Heat to boiling. Cool. Now neutralize by adding a little powdered sodium carbonate (test with litmus). Test as above with Fehling's solution. Result? (See page 605.)

3. Test for fats and oils.

Place a drop of oil on a piece of paper. Hold to the light. Result?

Put a spoonful of cornmeal or crushed peanuts in a test tube. Keeping away from a flame, add enough benzene or ether to cover. Shake. Allow to stand. Pour a few drops of the clear liquid on a piece of paper. Examine against the light. Result? (See page 606.)

4. Test for proteins.

Place a little of the white of a hard-boiled egg in a test tube. Add a few drops of nitric acid (conc.). Colour? Wash off the acid with water. Add a few drops of ammonium hydroxide. Colour? (See page 608.)

5. Test for mineral matter.

Place half a teaspoonful of oatmeal on a porcelain crucible cover. Heat strongly (under a hood), till all the carbon is burned away. Result?

Samples of food such as bread, cheese, beans, lean meat, can

be tested for each of the above ingredients. If these tests are made, tabulate your results.

EXAMINATION FOR THE ACID RADICAL

The following scheme is for the identification of the anions: Carbonate ($CO_3^{=}$), sulphite ($SO_3^{=}$), sulphide ($S^{=}$), chloride (Cl^{-}), bromide (Br^{-}), iodide (I^{-}), nitrate (NO_3^{-}), phosphate ($PO_4^{\equiv}$), sulphate ($SO_4^{=}$), nitrite (NO_2^{-}).

Group A

To a portion of the original solution, add dilute HNO_3. No gas evolved. Pass on to Group B.
If a gas is evolved:

(1) Gas is odourless—test with lime water. If carbon dioxide is present, this indicates a **carbonate.**

(2) Gas has sharp odour—SO_2—a **sulphite.**
Confirm by holding a drop of K_2CrO_4 on a glass rod in the gas—drop turns pale green.

(3) Gas has odour of rotten eggs—a **sulphide.**
Confirm by holding paper soaked with lead acetate solution in gas. Paper turns brownish-black.

Group B

To a portion of original solution, add $AgNO_3$ solution. No ppte. Pass on to Group C.
A ppte. is produced:

(1) White ppte.—a **chloride.**
Confirm by adding NH_4OH in excess. Ppte. dissolves.

(2) Cream-coloured ppte.—a **bromide.**
Confirm by adding a little MnO_2 and conc. H_2SO_4 to original solution and warming. Brown fumes of bromine.

(3) Yellow ppte.—an **iodide.**
Confirm with MnO_2 and H_2SO_4 as above.

Note: a yellow precipitate here may be silver phosphate. (See Group D.)

Group C

Place a square of clean glass on a sheet of white paper on the desk. On the glass put close together a drop of the solution to be tested, a drop of ferrous sulphate solution and a drop of conc. H_2SO_4. With a glass rod bring these together. A brown colour (not to be confused with the shadow of the liquid on the paper)—a **nitrate.** Note: The brown-ring test as given on page 288 of your text may be substituted.

No brown colour, pass on to Group D.

Confirm by adding a little conc. H_2SO_4, and some copper turnings to original solution. Warm. Brown fumes.

Group D

To about 2 cc. of ammonium molybdate in a test tube, add about 1 cc. of original solution to which a little HNO_3 has been added. If no immediate reaction, warm a little (do not boil) and allow to stand.

No yellow ppte. Pass on to Group E.

Fine yellow ppte.—a **phosphate.**

Confirm by adding $AgNO_3$ to original (neutral) solution. Yellow ppte. soluble in HNO_3 or in NH_4OH.

Group E

To a portion of the original solution add $BaCl_2$ and dilute HCl.

White ppte.—a **sulphate.**

Confirm by boiling. Ppte. remains.

Group F

If the salt is insoluble in water treat as follows:

Put a small quantity of the salt in a test tube and add a little conc. H_2SO_4. Warm.

(a) Gas colourless—identify as in Group A above, or if cloudy fumes are produced on breathing across mouth of test tube—a **chloride.**

(b) Gas brownish—a **nitrite.**

After trying several of the tests, ask your teacher for an unknown salt (solid). Use part of this salt for determination of the cation and part for determination of the anion. Keep a complete record of the tests you make, recording all negative as well as positive results.

FIRST AID

In case of an accident or injury, notify your instructor at once.

Treatment for common types of injuries in the laboratory.

Acids—

On the skin—Wash with plenty of water. If severe, dress with a paste of sodium bicarbonate.

On the clothing—Saturate with dilute ammonium hydroxide.

Internal—Drink lime water, milk of magnesia or baking soda solution.

Bases—

On the skin or clothing—Wash with plenty of water. Then apply a boric acid solution. Wash again.

Internally—Drink juice of a lemon or orange.

Burns—

Apply a paste of sodium bicarbonate and water.

Cuts—

Clean with water. Apply tincture of iodine or hydrogen peroxide. Bandage.

SCHEME FOR THE IDENTIFICATION IN SOLUTION OF ONE OF THE FOLLOWING CATIONS

Ag^+, Pb^{++}, Hg^+, Hg^{++}, Cu^{++}, As^{+++}, Sb^{+++}, Al^{+++}, Fe^{++}, Fe^{+++}, Zn^{++}, Ca^{++}, Mg^{++}, Na^+, K^+, NH_4^+.

A. To the solution to be tested add a few drops of dilute HCl. If this gives a ppte. add more acid till precipitation is complete. Examine according to I. If no ppte. is formed pass on to B.

I. Ions giving insoluble chlorides—Ag^+, Pb^{++}, Hg^+.

Divide the ppte. in A, into two parts. To one part add NH_4OH, to the other dilute HNO_3. Shake.

(a) Ppte. dissolves in ammonia but not in nitric acid.—**Silver.**
Confirm by standing some of the ppte. to the light.—It darkens.

(b) Ppte. darkens on adding ammonia, but does not dissolve.—**Mercurous.**

(c) Ppte. remains unchanged. Allow to settle. Pour off supernatant liquid. Boil ppte. in half a test-tube of water. If ppte. dissolves—**Lead.**
Confirm by adding K_2CrO_4 to original solution — deep yellow ppte. of lead chromate.

B. Test a little of the acidified solution from A by passing H_2S through it. If a ppte. is formed, pass H_2S through the whole solution from A. Examine according to II. If no ppte. is formed, pass on to C.

II. Ions giving insoluble sulphides in acid solution.—Hg^{++}, Cu^{++}, As^{+++} Sb^{+++}.

(a) Yellow ppte.—**Arsenic.** Note: a pale yellow ppte. may be sulphur from the H_2S, if solution is strongly acidic or if a sulfite is indicated under the anion tests.

(b) Orange ppte. — **Antimony.** If ppte. is black or dark brown, boil in dilute HNO_3.

(c) Ppte. does not dissolve. —**Mercuric.**
Confirm by adding freshly prepared stannous chloride to original solution. A grey or black ppte.

(d) Ppte. does dissolve.—**Copper.**
Confirm by adding potassium ferrocyanide to original solution. — A chocolate ppte. of copper ferrocyanide.

C. Add several cc. of NH_4Cl solution to the solution from B which was not treated with H_2S. Add NH_4OH in excess. (Shake and test with litmus to ensure alkalinity.) If a ppte. is formed examine according to III.

III. Ions giving hydroxides insoluble in basic solutions.—Al^{+++}, Fe^{++}, Fe^{+++}.

(a) White, gelatinous ppte. —**Aluminum.**
Confirm by heating a little of the ppte. on charcoal, using a blowpipe. Add cobalt nitrate solution. Heat again—a light blue colour.

(b) Greenish ppte. — **Ferrous** (iron).
Confirm by adding a few drops of potassium ferrocyanide to the original solution—a light blue colour.

(c) Rusty or reddish ppte. —**Ferric** (iron).
Confirm as in (b)—a dark blue ppte.

D. If no ppte. obtained so far, add $(NH_4)_2S$ to a portion of the alkaline solution in C.—White ppte. (coloured yellow with amm. sul.)—**Zinc.**

E. If no ppte. so far, add ammonium carbonate solution to another part of alkaline solution from C.
White ppte.—**Calcium.**
Confirm with flame test (See exp. 7)—orange-red colour.
Note:—Strontium and barium may also be detected here and confirmed by the flame tests.

F. If no ppte. so far, add disodium phosphate to solution from E.
White ppte.—**Magnesium.**

G. If no ppte. so far, concentrate some of the original solution by evaporation. Add NaOH and heat.
Odor of ammonia—**Ammonium.**

H. If no odour of ammonia in G, apply flame test to original substance or original solution.
Lilac flame.—**Potassium.**
Strong yellow flame.—**Sodium.**

BIOLOGY 2

The following exercises are designed to aid the student of Biology in carrying out a number of individual experiments. It is not expected that all those listed should be completed, but an effort should be made to perform as many as possible. Nor is it intended that they should replace those outlined in the textbook. Many of these, also, should be performed by the student. Students should be encouraged to learn much of their Biology from actual observations, rather than by merely reading the textbook.

Many of the details of the experiments may be modified to suit the local conditions.

Blueprints make accurate and permanent records of many experiments.

The teacher should write for "Turtox Leaflets," supplied free by the General Biological Supply House, Chicago. These give very helpful instructions on such items as "Mounting Insects," "Making an Aquarium," "The Feeding of Minute Animal Organisms," etc. The catalogue of this Supply House is most helpful to teachers of Biology, and may be obtained upon request.

LIST OF APPARATUS AND MATERIALS

Aquarium
Beakers, 400 cc.
Beakers, 250 cc.
Cellophane sheets
Cheesecloth
Chemicals—
- Alcohol
- Ammonia
- Carbondisulphide
- Chloroform
- Eosin dye
- Fehling's solution
- Iodine
- Nitric acid

Cotton wool
Cotton batting
Cover slips (for microscope slides)
Dissecting board
Dissecting needles
Dissecting pan
Flower pots, 3″
Flower pots, 4″
Forceps
Jars (of various sizes)
Knife
Lamp chimneys
Magnifying glasses
Microscope (with high power and low power)

Microscope slides
Petri dishes
Pins
Sand
Sawdust
Soil
Riker mounts
Wooden flats
Vials (wide mouth, glass)

OUTLINE OF PRACTICAL WORK

1. USE OF THE MICROSCOPE

1. Learn names of the parts of the instrument; e.g., stage, aperture, diaphragm, mirror objective, eyepiece, etc. There should be screws for coarse and for fine adjustment. Mirror should have plane and concave sides.

2. Preparation of object for viewing:

The object must be transparent, a very thin section of plant or animal tissue, or protozoans, aphids, water fleas, moulds, algae, etc.

Place the object on a clean glass slide; place a drop of clean water on it (dry specimens do not transmit light efficiently), cover with a cover glass.

3. Place the specimen prepared as above on the stage, and centre it over the aperture.

4. Turn the mirror below the stage toward the source of light. If the light comes from a window, use the plane side of mirror; if from a lamp flame or filament, use the concave side.

Tilt the mirror until you see the beam of light pass through the glass slide and specimen.

5. See that the low-powered objective is in place above the specimen. With your eye on the level of the stage, turn the objective down until it almost touches the cover-glass. (Never turn screws to lower objective, with your eye to the eyepiece, unless the specimen is plainly in view.)

6. Now place your eye above the eyepiece. Light should be coming through to your eye. Turn the screws to **raise** the objective. Continue until image of specimen comes into view.

7. Now that you have the specimen in view, several improvements may be made. Experiment with mirror and with diaphragm until you have the best possible light arrangement. With eye still placed to the eyepiece, take the slide on which specimen is placed in both hands and move it gently back and forth to view different parts of specimen.

8. If you desire a higher magnification, there are several methods you may adopt. You may replace the eyepiece with one of higher power. You may raise the eyepiece by lengthening the

tube between objective and eyepiece and then re-adjusting the focus. Or you may replace the objective with one of higher power. For the high power objective you will need more light.

2. THE AQUARIUM

Every biology classroom should have an aquarium. Complete instructions on making one will be found in "Everyday Biology," pages 636-8. Water weeds may be anchored to the bottom by tying a glass stopper or a piece of glass tubing to the lower end of the plant. Roots should soon strike into the sand. In addition to fish, snails should be present. If the aquarium is a large one, salamanders may also be stocked. However, these have a tendency to attack the fish, and so are better kept by themselves. If it is desired to hatch frog tadpoles from eggs, or young snails from eggs, the fish must be removed. If the water becomes murky, it probably indicates the presence of too many animals.

THE TERRARIUM

"Everyday Biology" also gives directions for the making of a terrarium (page 645). A desert terrarium, including a few cacti and "horned toads," makes a very interesting display. "Horned toads" (lizards) may be obtained from the Biological Supply House, Chicago.

3. MICROSCOPIC ORGANISMS

(For all students)

Materials: Small quantity of organic matter: a handful of grass, dry hay, dead leaves, slices of carrot, etc.

Procedure: Place any of the above in a jar of water and leave in a warm place, 70-90 degrees Fahrenheit, for several days.

Take a clean glass slide. Place upon it a drop of clean water. Pluck a few threads from an old piece of clean cotton and pick them apart with a needle until the fibres are very finely divided. Place these in the drop of water on the slide. These fibres form a trap which restricts the movements of the protozoa and allows the observer to keep them in view.

Now take a sample of the infusion from the jar and place a drop of it among the wet fibres. Cover with thin glass. Examine with the low power objective of the compound microscope. There are certain to be paramecia and other ciliata, and you may be fortunate enough, if your infusion was made with decaying leaves, to find amoebae. The latter are more likely to be found at the bottom of the jar.

Water from Sloughs and Ponds—

Samples should be collected from as many of these sources as possible. If there is a green scum on the water there are sure to be algae, such as closterium, ulothrix, spirogyra.

On the edges of leaves under water, the protozoan, vorticella, is usally found. Place the wet leaf on a slide and bring the edge of leaf into sharp focus with the low power of microscope. Then move the slide carefully, keeping the edge always in view.

Vorticella may be recognized by its bell-shaped body, the ring of waving cilia around the mouth, and by the long coiling thread which attaches it to the leaf. Larger organisms, rotifers, cyclops, daphne, etc., visible to the naked eye, may also be found in pond water. These make suitable specimens for microscopic studies.

Soft jelly-like masses may often be found on decaying wood in pond water. These are fresh sponges. Some ponds contain hydra, usually found on the stems of bullrushes under the surface of the water.

4. BACTERIA

(For several students)

Bacteria are minute fungus plants that are either parasites or saprophytes. They are widely distributed and can be grown on artificially prepared media.

Materials: Beaker 400 cc.; test tubes; funnel; flask; cotton wool; Petri dishes; burner; water; agar-agar; beef extract; a piece of cotton.

Procedure: Into the beaker containing about 200 cc. of distilled water, put 3 grams of agar-agar and about 1 gram of beef extract. Dissolve the agar-agar by heating the water. Strain through cotton into a flask and heat again.

Sterilize the Petri dishes and test tubes by boiling in water for 5 minutes. Pour the sterile medium into the Petri dishes or half fill the test tubes. Cover the dishes and plug the test tubes with cotton wool. Rest the test tubes at an angle to form a larger surface. Allow the liquid to stand till cool and firm.

Set one test tube aside as a control.

Remove the cotton wool from a test tube or the cover from a dish and expose contents to the room air for ten minutes. Cover as before and label. Similarly expose other culture media to (1) a drop of dirty water, (2) a drop of milk, (3) dust from the desk, (4) your finger. Cover and label. The dishes containing the drops of liquid should be shaken to spread the liquid. Set the dishes in a warm dark place.

Examine after several days. Note the number of colonies, colour, shape, rate of growth. Record your observations. When a culture is sufficiently developed make an accurate record in the form of a drawing.

5. MOULDS

(For several students)

Materials: Saucer; large beaker; piece of bread.

Procedure: Moisten a piece of bread. Either leave it exposed for several hours, or sprinkle with dust from two or three

sources. The bread may be dusted with other mould spores, if available. Cover the bread with the beaker, and set aside in a warm place. Examine daily. When growth begins, examine closely with a magnifying glass, and under the microscope.

Record your observations with diagrams.

Several kinds of moulds may be found.

If you have been successful in obtaining the "black mould," place a black sporangium (see page 125 in textbook) on a glass slide. On it place a cover slide and press gently so as to crush the sporangium. Now examine under the microscope, first low, then high power.

Additional Experiment on Moulds

(For all students)

Materials: Test tubes; cotton wool; clear fruit juice.

Procedure: Put a few cc. of fruit juice into 2 or 3 test tubes. Add an equal volume of water. Shake. Inoculate the liquid by adding a little mould to it, or by sprinkling it with dust. Plug the test tubes with cotton wool, and set in a warm place.

Observe as above and record your observations.

6. DISSECTION OF EARTHWORM

(For pairs of students)

Materials: Dissecting pan; forceps; scissors; dissecting needles; pins. Dissect under water, renewing water frequently.

1. Lay the specimen on board, dorsal side uppermost; stretch and pin at ends, slanting pins away from the worm. Make an incision through the skin near the posterior end and to one side of the dorsal blood vessel. With scissors cut forward along a line parallel to the intestine until the anterior end is reached. With forceps, lift the cut edge of the body wall and run a dissecting needle along the side of the intestine to cut the partitions that extend from intestine to body wall. Turn the edges of the body wall back and pin them down, slanting the pins so that they are out of the way.

2. The intestine is the most prominent organ disclosed. It is dark-coloured from its contents and nearly fills the body cavity.

3. Along the top of the intestine is the dorsal blood vessel.

4. With a lens, observe the partitions. How do they correspond to the segments you have observed in the external surface?

5. In the first six segments (anterior end) you will find more muscle tissue than in the remainder of the body. These are attached to the pharynx.

6. On the dorsal side of the second segment you should see two ganglia, white masses of nerve tissue which serve as a brain.

From these, a nerve cord passes on either side of the pharynx to rejoin in a thin white thread which extends the entire length of the ventral side. You may be able to see it with a lens.

7. In the region of the tenth segment are the sperm sacs, several pairs of white bodies, plainly visible.

8. Lying in segments eight to twelve are the aortic arches. These serve as hearts to pump the blood. They can be traced from the dorsal blood vessel to the ventral blood vessel. The aortic arches may be seen best by anesthetizing a living worm (chloroform or ether), and holding it up by the extreme posterior end, swinging it around several times until the centrifugal force causes the blood to collect in the anterior end. If it is then opened, the aortic arches will be found distended with blood.

9. When the sperm sacs are removed, you may find in the ninth and tenth segments two small pairs of white spherical bodies, the sperm receptacles or spermathecae.

10. The ovaries may be found in the thirteenth segment.

11. Trace the alimentary canal. The mouth occupies segments one and two; the pharynx, four to five; the oesophagus, six to fourteen; the crop, fifteen to sixteen; the gizzard, seventeen to eighteen. The intestine occupies the remaining segments.

12. Remove the intestine, noting the ventral blood vessel and nerve cord.

13. Attached to the ventral side of each segment is a pair of tubes thrown into many loops. These are the nephridia or kidneys.

14. Examine the body wall under a lens and later with microscope. The outer layer peels off easily and is very thin. This is the cuticle. The next layer is composed of circular muscles, and the third, of longitudinal muscles.

15. Mount a drop of liquid found in the body cavity under the microscope. The white corpuscles are clearly seen.

7. THE GRASSHOPPER

(For all students)

Materials: Grasshopper; dissecting needle, or large pin; forceps; magnifier; white paper.

Procedure: Examine the general structure of the insect, using the magnifier as an aid. Note the three distinct body divisions. Name these. Draw the grasshopper (side view) and label the main features.

HEAD—Examine the head with the glass. Locate the following parts—feelers, compound eyes, simple eyes (ocelli), mouth, palps. With the aid of the forceps, carefully remove the mouth parts and arrange them on a sheet of paper in their relative posi-

tions—upper lip, lower lip, mandibles (hard, black jaws), maxillae (bearing palps), tongue.

Make a diagram of the mouth parts as arranged. Label each part. (Diagrams of mouth parts may frequently be found in reference texts.)

THORAX—Note the shape of the thorax and its three segments (prothorax, mesothorax, metathorax). Note the number of wings, their structure and shape. To what segments of the thorax are they attached? Compare the under wing and the top wing.

Examine the legs and note their insertion on the thorax. Hunt up in a reference text the names of the different segments of the leg.

ABDOMEN—Count the number of segments. Locate the spiracles and count them. The ear of the grasshopper can be easily seen on the front segment of the abdomen above the insertion of the large jumping leg. The end of the abdomen of the female is modified into an ovipositor or egg layer.

Using a sharp knife or razor blade, slice a thin section of the compound eye and examine under the microscope.

A cabbage butterfly may be examined if desired. A piece of a wing should be examined under the microscope to observe the scaly covering. This will be more easily observed if some of the scales have first been removed by rubbing the wing with the finger.

8. INSECT LIFE HISTORIES

(Class project)

Materials: Flower pots; lamp chimneys; cheesecloth; rubber bands; soil; plants or twigs for insect food.

Procedure: Collect insect eggs or larvae. Note the kind of plant upon which each is found in order to supply the proper food. Fill the pot with soil. Close the top end of the chimney with cheesecloth held with the rubber band. Place a young plant or twig in the soil. Add water. Put the eggs or larvae on the plant and set the chimney over the plant.

Make daily records of any changes which occur.

The develpoment of mosquitos from eggs can be readily watched by placing the eggs in a beaker of rain water (or slough water), setting the beaker on the soil and covering with the chimney.

Permanent Life History Exhibits

Suggested exhibits to be made by different groups of students are: Grasshopper, monarch butterfly, honey bee, potato beetle, cutworm, dragonfly, housefly, promethia moth, red underwing moth (catocala).

Cocoons containing living pupae of the large silk moths may be obtained from the General Biological Supply House, Chicago. When hatched, excellent exhibits of these may be made, showing the cocoon (outside and inside), pupal case (in cocoon) and adults (male and female).

Materials: Riker mounts (or cigar boxes, cotton batting and cellophane); small wide-mouthed vials; alcohol; specimens.

Procedure: Place a few eggs of the cabbage butterfly (the common white), obtained from the leaves of the cabbage in early summer, in a vial. Add alcohol and stopper tightly. Later place one good sized larva in a second bottle. Add alcohol and stopper. Repeat later with a pupa in a third bottle. Mount a specimen of the adult butterfly with wings spread. Do not use a pin in the thorax. The body may be held firmly in position in the groove of the mounting board by placing pins against the body behind the wings.

Spread a layer of cotton batting in the cigar box, sufficient to fill the box. Place the bottles and the adult insect in position on the batting. Identify each by a typewritten label. At the bottom of the exhibit place another label on which are shown the names (scientific and common), date collected, etc. Paste the sheet of cellophane over the box. The sheet should press lightly on the specimens. Riker mounts are more satisfactory than cigar boxes, but also more expensive.

9. CLASSIFICATION OF INSECTS

(For all students)

Materials: Several specimens of insects, including some of the following: Housefly, grasshopper, moth or butterfly, bee, dragonfly, potato beetle, stink bug, mosquito.

Using the following key, classify each specimen:

Key

	Order
With two wings only	Diptera
With four wings—	
Outer pair of wings hard and shell-like	Coleoptera
Outer wings with the front half hard and the rear half membranous	Hemiptera
Wings much alike—	
Both pairs of wings colored; covered with scales	Lepidoptera
Wings thin and transparent—	
Outer wings folded over inner fan-like wings; held close along body when at rest	Orthoptera
Wings held at right angles to the body—	
Mouth parts for sucking and Chewing	Hymenoptera
Mouth parts for chewing	Odonata

In your note book (1) copy the "key", (2) write down the Orders listed in the key with the name of insects classified in each Order.

10. DISSECTION OF FROG

(For small groups of students)

Materials: Frog; dissecting board; pan; dissecting needle; scissors; knife; forceps; pins; probing rod.

Procedure:

1. If the frog is living, place it in a wide-mouthed jar. Pour ether or chloroform on a piece of absorbent cotton and drop the cotton in the jar. Seal and leave for half an hour.

2. Place the frog on its back on a dissecting board. Stretch the forelegs well forward and tack them to the board. Stretch the hind legs well back and tack them. With forceps pinch up a fold of skin near the pelvis. With scissors, snip through the skin and slit the skin from pelvis to chin. Loosen the skin wherever it adheres to the underlying tissues and turn it back.

Cut outward from the centre line to each leg and slit part way along the leg. Pin the skin back so that it is out of the way.

Cut through the muscular wall of the abdomen and carry the cut forward in the same way as with the skin. Be careful to keep this cut a little to one side of the centre line and watch the point of the scissors to see that no internal organs are injured. Tack the flaps of the abdominal wall.

3. The most prominent organs in the body cavity are the liver, and, if the frog is a female, the oviducts. It may be necessary to lift or remove these to see the other organs. The liver is chocolate-coloured and has several lobes. If the oviducts are filled with eggs they will appear black, owing to the colour of the eggs; if not, then they appear as long white tubes. They must not be confused with the intestine.

4. At the anterior edge of the liver and between the lobes is the reddish heart. It is enclosed in a very thin transparent sac, the pericardium. Pinch this up with the forceps, cut through it and remove most of it. If the frog is freshly-killed, the heart may be still beating. The main artery from the ventricle divides into two branches, right and left, and each of these into three subdivisions: 1, to the head, the carotid; 2, to the body, the aorta; 3, to the lungs and skin, the pulmo-cutaneous.

You may puncture the heart and probe with a blunt wire to trace the arteries and veins. Later, if you wish, you may dissect the heart.

5. On either side of the heart and partly hidden by the liver are the two lungs. If they are collapsed, they may be inflated with a glass tube or blowpipe applied to the glottis. Compare them with lungs of a bird or mammal.

6. Push the liver aside to expose the stomach. Probe from the mouth through oesophagus to stomach with a blunt rod.

7. At the posterior end of the stomach is the intestine. Trace it throughout its course. How does it compare in number of folds with: a fish? a duck? a chicken? or a rabbit?

8. Notice the thin membrane which stretches from fold to fold of the intestine. This is the mesentery. Where is it attached to the body wall? Notice the blood vessels which form a network in the membrane. Where are the capillaries which connect arteries and veins?

9. The pancreas lies in the first fold of the intestine and the stomach. It has the appearance of a yellow cord with lateral branches.

10. The intestine empties into an organ called the cloaca. This receptacle receives the wastes from the intestine, the urinary bladder, and also the sperms or eggs from the reproductive organs.

11. On the dorsal side of the body cavity and on either side of the cloaca is a flattened, reddish body, the kidney.

12. Near the ventral surface of each kidney is the spermary or ovary, depending upon the sex of the frog. Sperm ducts or oviducts lead from these to the cloaca.

13. The spleen is a small red spherical body close to the left kidney.

14. The thyroid glands may be found on either side of the oesophagus near the pharynx.

11. CORPUSCLES OF FROG OR FISH

A live frog is enclosed in a small cloth bag with a drawstring tightened around the hind leg so that only the foot protrudes.

The bag may be secured with strings to the stage of the microscope so that the webbing of the extended foot is over the aperture and under the low power objective.

The webbing of the foot is sufficiently transparent to enable the student to watch the corpuscles flowing through the veins and capillaries.

An even better view of corpuscles, coursing through blood tissues, may be seen in the tail of a goldfish or minnow. Wrap the live fish in a clean wet cloth with only the tail protruding. Place the tail on a wet glass slide and view under the low power of the microscope.

Tadpoles may also be used for this purpose, if they are caught in the stage when they are breathing by external gills. The circulatory system where it passes through the gills may easily be seen. The tiny tadpole can be placed on the glass slide with its gills in contact with the glass.

12. GERMINATION OF FERN SPORES

(For two or three students)

Materials: Culture dish or saucer; small unglazed plant pot, 3″; large beaker; moss (sphagnum moss, if available); fern spores; water.

Procedure: Fill the pot with the moss or some suitable substitute. Wet moss and pot thoroughly. Invert the pot with moss and place on the bottom of a Petri dish or in the saucer. Dust the fern spores (from sporangia) liberally over the damp pot. Add a little water to the dish and cover with a large beaker. Set aside at room temperature. These spores may take weeks to germinate.

Examine from time to time and when germination begins, as seen by the green colour, remove a few prothallia to a glass slide. Add a drop of water and cover with a cover slip. Examine under the low power of a microscope.

Make a cross section diagram of the apparatus and label. Draw several successive stages in the germination as seen under the microscope.

13. STRUCTURE OF MONOCOTYLEDONS AND DICOTYLEDONS

(For all students)

Materials: Young stems of plants; geranium, fuchsia, lilac, maple, etc.; ink or dye; razor blade; magnifier; microscope.

Procedure: (1) **Stems: Dicotyledons.** Make thin slices of stem of geranium, fuchsia, etc., and examine them under the low power of the microscope. Cut stems of the same plants and of lilac, willow, maple, etc., with vigorous leaf systems. Place the cut ends in a jar of dye (eosin, weak solution of red ink, etc.). Leave for one or two days. Remove and slice thin cross sections.

Notice the tissues that have carried the dye. How are they arranged? (The wood cells, xylem, carry liquids upward in the stem.)

Examine the slices with a hand lens and with a microscope. Notice the epidermis, the cortex, bast, wood, and pith. The wood should show the stains from the dye. The bast should be uncoloured, but should be in the same bundle with the wood and toward the outer edge of the stem. Cells of pith and cortex are much larger than wood and bast cells, the pith in centre of stem, and extending outward between bundles of wood. The cortex lies outside of the bast and extends inward between the bundles. The cambium layer is not a part to be seen as a distinctive type of cell. It is the region of growth, and new cells of wood, bast, pith and cortex are being formed there during the growing season. When cells are growing most rapidly the walls will be weak, and a sharp twist will sometimes separate bast and cortex from wood and pith. (Every boy has done this in making willow whistles.) This is a good method for locating the cambium layer.

Stems: Monocotyledons. Repeat the above procedure with stems of corn, onions, lilies, cereals, dates. Dye rises in the wood, as before, but the coloured tissues will be found in a different pattern. Bast and wood are still bound in bundles, but these bundles are scattered in the pith.

(2) **Leaves.** Collect and compare leaves of monocotyledons and dicotyledons. Generally speaking the former are parallel-veined, and the latter, net-veined.

(3) **Flowers.** Collect and compare flowers of the two classes. Count the petals, sepals, stamens, lobes of stigma, sections of ovary, etc. Monocotyledons generally have these parts in multiples of three, dicotyledons, in multiples of four or five.

(4) **Seeds.** Collect and soak seeds of flowering plants. Remove the testa or outer covering; the origin of the terms "monocotyledon" and "dicotyledon" should be clear. In dicotyledons, e.g., beans, peanuts, etc., the seeds should divide easily into two parts, the cotyledons.

14. FOOD CONTENTS OF SEEDS

(For all students)

Seeds contain one or more of the following food materials—starch, protein, fat, oil, mineral matter.

Instructions for making tests for determining the presence of any of the above materials may be found in Exercise No. 15 of the Chemistry experiments.

15. IDENTIFICATION OF TREES

(For all students)

During their study of Biology, students should become familiar with the names and appearance of several of the common trees and shrubs of the district. The following exercise should be carried out in the early spring, when the buds are beginning to expand.

Materials: Young, vigorous twigs (length 5") of several trees and shrubs: poplar, birch, maple, Manitoba maple, ash, elm, lilac, willow, tamarac, pine; magnifier; dissecting needle.

Procedure: Note carefully the following features:

(1) Colour and appearance of bark of stem.

(2) Relative position of buds on stem (opposite one another or alternate).

(3) Shape and colour of buds.

Remove one large bud and carefully dissect it, placing the scales and leaves on a sheet of paper in order as they are removed from the bud. Note the young stem which remains after all leaves are removed.

Make a drawing to show these scales and miniature leaves.

In your notebook, rule a page as shown below, leaving plenty of space for the drawings. Under the headings "Twig", "Bud" and "Leaf", make careful drawings of these parts. Rule a space for each plant examined.

Plant	Twig	Bud	Leaf
Lilac			

16. SEED STRUCTURE

(For all students)

Materials: Bean seeds and corn seeds soaked for 24 hours; magnifier; iodine (weak solution).

Procedure: Bean: On the testa or seed coat, find the hilum or scar where the seed was attached to the pod. Near the hilum is a tiny opening, the micropyle, which admitted the pollen tube to the ovule. Make two drawings of the bean, one side view, the other from above, showing the hilum. Label.

Remove the testa. Note the two cotyledons, held together by the embryo. Open the two parts, carefully breaking them apart. Locate the plumule or little leaves, and the stem or hypocotyl. Make a drawing and label.

Corn: Make two drawings of the corn seed—front and side views. Note the light coloured area—the embryo. Cut the seed lengthwise through the embryo. Stain the cut surface lightly with the iodine and note which part contains the starch. Observe the embryo—plumule, hyprocotyl and cotyledon. Make a diagram and label.

17. SEED GERMINATION

(For several groups of two or three students)

Materials: Flat wooden boxes; sawdust, sand or soil; bean seeds; pea seeds; corn seeds.

Procedure: Soak all seeds for 24 hours before planting. In the box, plant 20 to 30 seeds of each kind. Keep the sand moist,

but not too wet. Dig up a few seeds every other day and record, by labelled drawings, the successive stages in the growth of the seedlings.

This experiment may be varied to suit the size of the class. If desired, a number of seeds may be planted at intervals of three days, thus giving, in time, a complete series of stages of growth. One class period would then enable the students to record the complete series.

By keeping some boxes in bright light, while others are kept in a weaker light, the effect of light upon the growth of the seedlings may be studied.

In small classes, students (in pairs) may be required to carry out the entire experiment.

Among the factors to be noted are:

(1) Time required for germination.

(2) First part of embryo to break through the testa.

(3) Part to appear first above ground.

(4) Position of cotyledons in seedlings.

(5) Rate of growth.

MUTILATION OF SEEDLINGS AS METHOD OF STUDYING FUNCTIONS OF DIFFERENT PARTS

(For several students)

In trays, plant rows of seeds. Sawdust is easier to use than soil. When germination has taken place and the leaves are beginning to appear above the surface of the sawdust, dig up specimens carefully; from one cut off the cotyledons or remove the endosperm; from another remove the radical; from another the plumule. Replant all parts, labelling them with distinctive numbers or words. Continue to water all specimens. Keep a record of their subsequent progress. Be sure to leave two or three plants uninjured as a control.

18. FLORAL STRUCTURE

(For all students)

Materials: A few complete flowers, such as lily, radish, petunia, buttercup, sweet pea; needle; magnifier; forceps; white paper; knife.

Procedure: Examine the whole flower, noting the different parts from outside and inside. Cut the flower through the middle and make a drawing of the parts observed. The base of the flower is known as the receptacle. On this are the sepals composing the calyx. Note their shape, colour, size, number and

whether they are united or separate. The next envelope is the corolla, composed of petals. Examine these as you did the sepals. The stamens consist of filaments and anthers. Examine the anthers carefully, cutting them open to observe the pollen grains. Examine some pollen under the microscope. In the centre of the flower is the pistil. It consists of ovary, style, and stigma. Feel the stigma.

Complete the following table in your notebook. Make drawings under the heading "shape."

Part	Colour	Shape	Composed of	Function
Receptacle				
Calyx				
Corolla				
Stamen				
Pistil				

19. GERMINATION OF POLLEN GRAINS

(For several students)

Materials: Petri dishes or saucers; sugar; water; pollen grains of several kinds of flowers.

Procedure: In 100 cc. of water dissolve about 1 gram of sugar. Boil for a few minutes. When cooled pour a little solution into each of the dishes. Dust some pollen grains from the anthers of a flower onto the solution. Cover and set in a warm place till next day. Examine some drops of water under the microscope—first low power, then high power.

Make drawings of your observations.

20. SNAILS' EGGS

An interesting study may be made of cleavage of fertilized cells and embryonic development if a few mature snails are kept in a glass jar in the classroom.

Egg clusters are deposited on the sides of the jar. These may be scraped off with a sharp knife and examined under the microscope. Sperms may sometimes be detected under the high power objective, swimming in the water surrounding the eggs.

If taken soon after fertilization takes place, the egg may be seen going through the process of cleavage. The one cell may be seen dividing into two, the two into four, and so through other successive stages, blastula, gastrula until shells are formed and the young snails are ready to emerge from their gelatinous envelope to forage for themselves and live their independent lives.

21. WEEDS OF ALBERTA

(For all students)

Materials: Complete specimens of several weeds common to your locality. Magnifying glass.

An herbarium of weeds should be prepared for every biology laboratory. These specimens should show as many parts of the plant as possible, and after being pressed and dried between large sheets of blotting paper, they should be neatly mounted on regular mounting sheets, and accurately labelled. Thick roots should have the back sections cut away. Freshly collected weeds are, however, preferable for study.

Coloured charts of Alberta weeds may be obtained from the Department of Agriculture, Edmonton.

Using a full page in your notebook, rule a table, as shown below. Under the headings—"Leaf," "Flower," "Seed or Fruit," make drawings of these parts respectively. Ten or twelve of the noxious weeds in your neighborhood should be examined.

Weed	Habitat	Leaf	Flower	Seed or fruit	Character-istics

EDMONTON: Printed by A. Shnitka, King's Printer.
1949.